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A Guide to the Ants of the Great Smoky Mountains National Park, Tennessee

A. C. Cole, Jr.

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Introduction

The impressive expansiveness and diversification of habitats of the Great Smoky Mountains National Park entice the biologist and test his ability to assemble and analyse the information which leads to possible explanations of distribution. Since 1936 the writer has been much interested in the insect fauna of the region, and from then until the present time he has been engaged in studies of the ants. These studies have culminated in the present paper which deals only with the Formicidae of the Tennessee side. Such a restriction is of course not intended to be a natural one, but has been necessary because of a lack of time and funds with which to survey completely the Park region as a whole. It is hoped that future investigations in the North Carolina Park area will permit of publication of a similar paper. From collections of ants made by the writer on the North Carolina side, it is evident that some species there may not inhabit the Tennessee Park area; but on the whole the ant faunas of the two sides seem to be very much the same qualitatively.

Collections were made and data accumulated in all seasons, and the summer of 1939 afforded the author the opportunity to camp in the Park and to spend his full time studying ants. At the close of that season it was apparent that a paper on this research, though still obviously incomplete, should be published. Thus has this guide come into being.

The purpose of the guide is three-fold, and the scope is such that this be possible. Fundamentally it is, and has been so planned as, a tool for those who may wish to study ants in the Park; and as such contains in simplified form the necessary keys, descriptions and distribution data for this work. Secondarily, it serves as an expression of the interpretations and opinions of the writer; and it is hoped this portion of the study will be of interest to advanced myrmecologists, especially as differences in opinion and interpretation may be encountered. Finally, the guide provides a list of the ants now known to inhabit the Park and thus is comparable in scope to lists from other physiographic regions.

Puzzling though it is, relatively little information has been published concerning the ant fauna of the Park, and few myrmecologists have collected in the region. In past years, Dr. C. H. Kennedy, of Ohio State University, vacationed in the now practically defunct town of Montvale Springs nestled in the Chilhowee Range foot-hilling the Smokies. From that base he rode and hiked in the mountains travelling among other byways the then winding dirt road leading to Newfound Gap and Clingmans Dome—a route which is now smoothly paved and traversed by thousands of automobiles each season. Pioneering the region myrmecologically, Dr. Kennedy made collections in many places. From Indian Gap, on a spot which the modern highway has almost completely obliterated, he collected specimens of an ant which he and Dennis together described as new to science (Kennedy and Dennis, 1937, pp. 542-544). Dennis (1938, pp. 284, 292-293, 300) in his paper on Tennessee ants lists only three species from the Park, these having been collected by Kennedy. Dr. Mary Talbot, of Lindenwood College, St. Charles, Missouri, spent three days during the summer of 1939 collecting ants in the Park, and she has kindly provided

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me with her list and specimens of thirty-five different collections. In this lot are thirty different species, subspecies and varieties. With four exceptions I have checked the determinations of these. *Myrmica punctiventris* was determined by Dr. Neal Weber of the University of North Dakota. Further records of collections of ants from the Park have not been found although undoubtedly a few may exist in rather inaccessible heterogeneous collections. The writer has published two papers (Cole, 1938, 1939) on ants of the Park which describe three species as new to science. Thus far, therefore, a total of four ants has been described from the region.

The writer gratefully acknowledges the kindly cooperation of the National Park Service personnel at Gatlinburg; the sound comments and criticisms of Dr. M. R. Smith, U. S. Bureau of Entomology of Plant Quarantine, Washington, D. C.; the helpful suggestions of Dr. S. A. Cain, Department of Botany, University of Tennessee; and the interest and patience of fellow nature enthusiasts with whom have been spent innumerable pleasant hours.

Geologic and Climatic Features of the Park

The Great Smoky Mountains are a part of the Blue Ridge Province of the Appalachian Highlands. The Tennessee-North Carolina state line traverses the crest and axis of the range at elevations around 6,000 feet. The valleys are spacious, "V-shaped and deep with rather steep but evenly sloping sides. Spurs spread out on several sides from the principal mountains, gradually descending to the valley levels. The general effect is one of an intricate much-branched valley pattern and of mountains pitched together with little semblance of order" (Cain *et al.*, 1937, p. 2). The metamorphosed sedimentary rocks are much folded, and the greater part of the Park is covered by Cambrian sediments. Ordivician limestones occur in the western portion. Geologically the mountains are very old, perhaps 60 millions years. The Great Smoky Mountains, with the rest of the Southern Appalachians, probably arose at the close of the Palaeozoic. Uplifts occurred during the Cretaceous and Pleistocene periods, with continuous erosion in progress. The mountains have never been completely inundated since the Palaeozoic, and hence have been available for living organisms for millions of years. "At this early date ferns and fern-like plants were in existence. Later, about the time of the elevation of the Sierra Nevadas, came the origin of seed plants. Forests had spread over the continent, even to polar regions, in the Eocene of the Tertiary Period at the time of the Laramide revolution which started the formation of the Rocky Mountains. By the close of the Tertiary cosmopolitan forests had developed. At the beginning of the Pleistocene numerous herbaceous plants were already developed contemporaneously with the ancestors of man. One can think of these southern mountains as having continuously been the theater where part of the grand story of biological evolution has unfolded—new species, from time to time, have played their first role there." (Cain *et al.*, 1937, p. 2).

When compared with the lower altitudes, the higher ones are characterized by much and frequent rainfall, averaging nearly 60 inches annually. Cloudiness and fogs are more common. Temperatures are lower, the summer average

in some areas being 70° to 80° F., and there is a shorter growing season. The average winter temperature is about 40° F. The soils are more acid and more sterile, and there is a greater accumulation of organic matter. Degree of slope varies greatly and there is a pronounced difference between directional exposures. The mountains above 5,000 feet are said to lie in the Canadian belt, in so far as climate and vegetation are concerned.

General Characteristics of Ants

Ants are cosmopolitan insects; that is, they are to be found in almost every place in the world where they are able to live—in deserts, on sand dunes and seashore, in luxuriant tropical rain forests and at timberline of the highest and most precipitous mountains. Many inhabit continuously cultivated areas, and reconstruct their nests after they have been routed out by the plow. About 8,000 species are known. They outnumber in individuals all other terrestrial animals, and even in small circumscribed areas their colonies may be extremely abundant. Many colonies are remarkably stable and frequently outlive generations of man. Ants have been known to live as long as fifteen years, and even the very active workers may have a life span of from four to seven years. This protracted existence is important for social insects, of which the ants appear to be the most highly evolved. In fact, ants represent the quintessence of social behavior.

Ants possess polymorphism, which means simply that there are several types of individuals within a species. With few exceptions they are at least trimorphic. This has resulted in a caste system and division of labor. The worker caste consists of those ants which attend to the construction of the nest and provisioning of the colony (society). They are wingless and for the most part nest builders and foragers and feed the other members of the colony with supplies they have transported to the nest, although they often serve in the capacity of protectors of their nest mates against invasion by foreign ants and other animals. Among the workers of many species there exists a distinct polymorphism, and thus there may be minor, medium and major workers based upon a scale of size. Even among the members of this caste the labor may be divided among the polymorphic forms in such a manner that each form has tasks of a definite nature to perform. Another caste which, however, is absent among some genera, is the soldier. Like the worker, this caste lacks wings. The soldiers are the guards and the protectors of the colony, although some have additional functions, such as moving the brood from one place to another, and perhaps in some seed-feeding genera, in cracking the hard shells of the seeds. The soldiers generally have remarkably large heads and powerful mandibles.

During certain seasons of the year male and female castes become evident in the colonies. These are winged. The males take no part in protecting the colony or in constructing or provisioning the nests. Their sole function is that of impregnating the females. The females, which are also winged before impregnation, are potential queens. As infertile females they take no active part in the economy of the colony. After mating, which generally takes place

in the air while the sexes are in flight, the males die; the females drop to the ground, rid themselves of their wings and in small chambers which they construct, deposit their first batch of eggs. After fertilization, the female is known as a queen. Wingless then, she is confined to her nest and to the all important activity of egg-laying. She feeds the larvae which hatch from her eggs, and after they have become grown and pass through a pupal or resting stage they emerge as workers. While this first brood of workers enlarges and provisions the nest and feeds new larvae, the queen becomes what may be considered an egg-laying machine, this activity being her sole duty as long as she lives.

Although the method of colony-founding described is not the only one employed by ants, it is nevertheless the most usual type. Additional kinds of importance, in so far as they occur in the Park, will be mentioned with the respective genera which employ them. It may be readily understood from the preceding brief résumé that ant colonies are essentially societies of females, the males being important only in respect to the perpetuation of the species. The queen is the biological center of her domain and all the activities of the society are concerned with the multiplication and care of future generations.

Ants possess a plasticity in their behavior which is truly remarkable. In their foraging and homing, their recognition of nest mates and aliens, their communication and their imitation they present activities which are little short of intelligent. Indeed, some myrmecologists and students of insect behavior have accepted this evidence as being definitely of an intelligent nature—a behavior dependent upon reasoning, primitive though it may be as compared with that of the highly specialized type of the human species. Be that as it may, it is sufficient to state here that as social insects, whose very existence demands a degree of plasticity in behavior, the ants are probably highest in this scale.

Ants feed upon a variety of substances, but most of them are scavengers, and their greatest usefulness to man is their power to hasten the decomposition of organic substances. Certain genera are seed-eaters, others feed upon the secretions and excretions of other insects; some are robbers and invade nests of other species for food; many are carnivorous and in hordes devour other ants and other small animals alike; while still others feed upon fungi which they cultivate in chambers of their own nests. These interesting food habits will be dealt with later in this paper together with the ants which possess them.

Some ants live in mixed colonies with those of another species, and apparently in complete harmony. Several genera include species which are temporary social parasites in nests of other ants; and we know of many slave-making ants which capture and enslave the brood of both allied and phylogenetically more distant species.

Equipment and Methods of Study

One who intends to begin a study of ants in the Park must provide himself with certain essential equipment so that he may not miss any of the many opportunities of study which await him. Collecting supplies need not be

expensive but should be adequate in quantity and quality and dependable in nature. I have found the following items to be indispensable:

A quantity of 1- and 2-dram homeopathic vials provided with a good grade cork and filled with 70% alcohol.
Two small mayonaise jars with cheesecloth covers.
A few small cyanide jars or vials.
Several long shell vials with cotton plugs.
Several cardboard pill boxes.
Garden trowel.
Hand axe.
Small camp shovel.
Forceps—with straight and with curved tips.
White sheeting, about one yard square.
Camera, with focusing ground glass, tripod and film.
Flat wooden marking stakes.
Notebook, pencil, pocket knife, twine and thermometer.
Knapsack, for carrying the supplies.

A series of specimens from a single nest should be placed in a vial of alcohol (rubbing alcohol will suffice), the size of the vial depending upon the size of the ants and the number collected. A numbered slip of paper should be placed immediately in the vial and the same number entered in the notebook. Small mayonnaise jars and long shell vials are desirable for retaining living nest samples, such as those to be transferred to artificial nests, and those of brood of the sexes which is allowed to emerge in order that the winged castes may be procured. Small cyanide vials are extremely useful for killing winged specimens which might otherwise be unsuitable for dried specimens if placed in alcohol. After the specimens have been killed they may be placed in a pill box bearing the same number as the vial of alcoholic specimens and as the notebook entry. I have found it advantageous frequently to kill both workers and winged castes in cyanide preparatory to almost immediate pointing on pins.

A sturdy garden trowel is necessary for digging into subterranean nests, and a hand axe for opening logs and cutting roots in earthen nests. A small shovel, which may be kept in the car, is of great advantage in rapid digging and for penetrating stony soil. Forceps, whose easy loss may be avoided by fastening them on a loop of twine hung around the collector's neck, are essential for collecting and transferring specimens. Collecting may be facilitated by placing all or part of the contents of an ant's nest on a square of white cloth where the contrast in colors makes the specimens readily discernible. White enameled wooden marking stakes may be placed beside nests which are to be revisited, the data in the notebook providing general location of the nests. A camera is essential for affording evidence of nest construction, such as mounds, and for photographing important habitats. I have chosen to use only Panatomic film, which has adequate speed, a wide latitude and is of fine grain. The use of the other equipment itemized is evident. All, with exception of the shovel, may be carried by the collector in a roomy knapsack, preferably one which straps on his back since the shoulder strap type bobs in his way while he crawls or otherwise bends his body forwards. I carry a small supply of vials in a breeches' pocket where it is available for immediate use. The forceps, if suspended by a cord from the neck, should always have their tips inserted into a cork while not in actual use. A deep stab will serve painfully to remind the investigator, if he be so careless as to disregard this protection.

The collecting supplies represent only a part of the equipment the myrme-

cologist must transport wherever he travels in the Park. Of prime necessity is a colletcor's permit. Such a permit is issued by the National Park Service headquarters at Gatlinburg, Tennessee, only to those investigators whose serious purpose it is to study a portion of the wild life of the Park. The Park Service is glad to cooperate with those who abide by Park regulations. The bearer of the permit, therefore, should consider himself privileged, but only to the extent that he use and not abuse the opportunities placed at his disposal.

Comfortable clothing of a fully protective nature is desirable. A small first-aid kit will be of constant use to the collector who, as he should, strays often and far from the numerous wide smooth well-beaten trails. Both rattlesnakes and copperheads live in the Park, and so the collector is wise if he include in his equipment one of the suction kits for venom extraction. Yet he may never see a poisonous snake in spite of his intimate association with warm rocky hillslopes. Chiggers abound in grassy areas during the summer months, but an external body coating of flowers of sulfur or sulfur capsules taken internally will rid the investigator of these pests. The little punkies, or no-see-ums, are pestiferous at times, but many lotions on the market will partially prevent or alleviate the irritation. A sizable canteen of water is frequently a thirst-quencher when the collector wanders far from running water during hot weather. A compass and a topographic map of the Park are often needed. Special equipment is necessary for other than simple ecologic studies.

For the benefit of those who may wish to begin work on ants, a few words of advice seem desirable. Never place more than a single collection from a single nest in a vial. The use of cotton plugs for separating layers of ants from different nests is false economy. Frequently, a few specimens will slip past a plug, and even if this should be avoided the cotton fibers entangle the ants' appendages in such a way as permits of exasperating sorting. Where possible collect a series of at least twenty-five specimens of workers; far more are desirable, since some may be used in exchange and the balance keeps indefinitely. If the specimens should prove to be those of a new, rare or otherwise especially interesting ant, the quantity can scarcely be too great. Many times I collect several hundred workers from a single nest.

The winged castes, males and females, should be collected and killed by cyanide, if they are to be used in a pinned collection. One can scarcely pick up too many of these, since in innumerable cases only they can adequately define the species. The genus *Myrmica*, for example, is determined to species primarily by the sexes. The box of winged individuals must bear the same number as the vial or vials of workers. Much time spent in attempting to locate the queen is not wasted, for she is a desirable and often a most necessary acquisition. For example, the Microgyna Group of the genus *Formica* is characterized by the unusually small queens, as the group name signifies. The queen is of course nothing more than a fertile female whose wings have been lost; hence she bears the characteristics of the female caste. Sometimes, in spite of prolonged raking of soil or teasing of wood, the queen just is not seen; and the collector can only hope that he will be more fortunate when and if he

finds another nest of the same species. The queen, since she does not bear wings, should be placed with workers in a vial of alcohol. The collector should make a point of securing representatives of all sizes of ants from a nest. It is usually impossible to determine certain ants to species if only single-sized individuals have been collected. The species of the genus *Pheidole,* for instance, are separated by the characters of the large-headed individuals (soldiers); the workers' structures tell the investigator practically nothing. Larvae and pupae from nests, if they are going to be preserved, should be fixed alive in Kahle's solution and then transferred to 80 per cent alcohol; or they may be placed, while still alive, in water at the boiling point but from which the flame has been removed, and after the water has cooled transferred into 80 per cent alcohol. Those who wish to rear the winged castes from nest pupae should keep a few workers with the pupae in a moist but ventilated place, since workers frequently must open the cocoons and groom the newly emerged sexes.

Geographical Distribution of Ants of the Park Region

Our present ant distribution may be accounted for on the basis of relics, endemics and migrants. The glacial epoch had a pronounced effect upon the ant distribution. South of the ice sheet a few of the more warmth-loving ants survived. These have persisted as relics. The recession of the ice sheet was followed by a northward migration of species. The unglaciated portion of the United States has retained an ant fauna very largely composed of well-known Eurasian genera and relics of a more southerly type. These relics which were comparatively few in the southeastern United States radiated many species, subspecies and varieties. They have spread and intermingled with the northern circumpolar ant fauna.

The southeastern United States has received many ants from the South American tropics via the Antilles, and has thereby been enriched greatly since the Pleistocene. Certain genera such as *Dorymyrmex* and *Iridomyrmex* and some species of *Ponera* (as *trigona*) and *Camponotus* (Maculatus Group) have reached the United States from the West Indies and from Mexico. The southeastern region is characterized by several species of *Dolichoderus (Hypoclinea),* three forms of which are known from the Park. The species of *Sysphincta* and *Proceratium* have been retained as relics. A few unusual species of *Aphaenogaster* (as *treatae* and *lamellidens*) and some forms of *Myrmica, Formica,* etc. originated apparently in the southeastern United States, and the subgenus *Dichothorax* of *Leptothorax* seems also to have had its origin there.

The cosmopolitan genus *Pheidole* is represented in the southeastern region by endemic forms. It is possible that these have been derived from relics of Mesozoic forms which were preserved in the southeastern and southwestern regions during the glacial epoch. The southeastern and southwestern centers exhibit some blending of forms as the result of migrations. There is little indication that the southeastern United States was an early center of specia-

tion. The region more probably constitutes only a secondary, more recent center.

It has already been pointed out that the Great Smoky Mountains are of great geologic age. Thus the region is undoubtedly the home of many ants old in the evolutionary scale. Furthermore, the possibilities for production of new species by mutation, as the result of isolation, have been enhanced. Twelve recent Palaearctic genera of ants are represented by Tertiary fossils in Baltic amber. [1] All are represented in the Park by one or more forms, and indeed most of them are cosmopolitan genera. They constitute about one-half the known Park genera. Forms of *Camponotus herculeanus, Formica fusca* and *F. sanguinea* extend over the entire north temperate region, whereas *Camponotus maculatus* is represented by subspecies and varieties on every continent and on many of the outlying islands.

A Comparison of Mountain Ants of Western and Eastern United States

There is a decided difference between the ant fauna of the eastern and the western United States. This may be explained by recognizing the difference in survival value after glaciation, since the ice sheet advanced much farther south in the eastern than in the western United States, and the Gulf of Mexico was an impassible barrier to the southward migration of western species. Therefore, there was less survival of eastern than of western forms. On a geologic scale, recently evolved species and subspecies are much more abundant in the Rocky Mountains than in the mountains of the eastern United States because of the considerably greater variety of physical conditions in the West. The Rockies run north and south through many degrees of latitude, have high timber and snow lines and are in many places broken by arid basins, some of which are large. Thus they represent a much more favorable region for the development of endemics. Such conditions do not prevail in the eastern United States. The eastern mountains, however, have a few species peculiar to them, and these probably represent survivors from Mesozoic and early Tertiary times.

Wheeler (1917) has studied the distribution of ants in the Transition and Boreal zones of the western United States (Pacific Coast, Sierra-Cascade and Rocky Mountain) and in a table he has summarized comparisons with and contrasts between them and Transition and Boreal forms of the eastern mountains (Wheeler, 1917, p. 483). The highest correlation is between the Rocky Mountains and the eastern mountains, since they have 12 species, 14 subspecies and 21 varieties in common, or 61.0 per cent. The resulting correlation when all the regions were incorporated in the data was low, being but 14.3 per cent—a percentage which exactly equals that obtained by omitting the Rocky Mountain data. The total number of endemic forms in the western fauna is 159, or 68 per cent, and in the eastern 75, or 32 per cent. The

[1] *Ponera, Monomorium, Aphaenogaster, Myrmica, Leptothorax, Crematogaster, Dolichoderus, Tapinoma, Prenolepis, Lasius, Formica* and *Camponotus.*

affinities between the Pacific Coast and eastern mountain faunas are least developed.

From the Park (Transition and Boreal) there are 7 species, 3 subspecies, and 10 varieties in common with the Transition and Boreal zones of the Rocky Mountains. The eastern region then has an ant fauna rather peculiar to it, with the exception of a certain number of holarctic and neotropical species.

Northern and Southern Elements of Formicidae in the Park

At the higher elevations of the Park live species which are distinctly boreal in habitat and represent elevational fringes of the more uniform and expansive northern distribution. Such species are generally well represented in the northern United States and have extended their range southward only at places where environmental conditions are satisfactory for their inception and establishment. For example, *Myrmica* is distinctly a boreal genus which is represented by several forms in the northern part of the continent. In Tennessee its distribution is restricted to cool moist habitats similar to those of more northerly latitudes.

Formica fusca is limited in the Park to the tops of the higher peaks, which is also true in the Rocky Mountains, although it is rather generally distributed in Canada and Newfoundland and in the extreme northern part of the United States (Maine, Vermont, upper peninsula of Michigan, etc.). Other boreal genera are *Stenamma* and *Myrmecina,* and they show a similar pattern of distribution.

On the other hand, the genera *Eciton, Dorymyrmex* and *Iridomyrmex* and the subgenus *Dichothorax* of *Leptothorax* are distinctly southern elements. Although they have broad distributions in the southern United States, their species in the Park[2] are found only in habitats which afford satisfactory conditions of temperature and moisture. Hence they are limited for the most part to the lower elevations which approximate more southerly climates. They have penetrated into the Park probably either by crossing the mountains through its gaps or have entered by way of the Mississippi Embayment. Thus the Smokies present an interesting group of both northern and southern elements. Southward distribution is favored by the peaks and northward distribution by the valleys.

The Ant's Environment and its Reactions to it

The Formicidae has definitely an important place as a prominent family in the entomological fauna of the Park. Although nowhere particularly abundant in species, the number of nests and individuals in the region is enormous. I have collected a total of 86 species, subspecies and varieties in the Park. Dennis (1938) lists 78 different kinds of ants from the entire state of Tennessee. Many of the trails seem literally to be overrun by ants.

2 The term "Park" as used henceforth in this paper will indicate only the Tennessee side.

Both qualitatively and quantitatively ants are most abundant in the valleys and on slopes at elevations between 1500 and 2000 feet. With altitudinal progression the number of species decreases regularly and noticeably as can be

TABLE 1.—Distribution, by Elevation, of Ants in the Great Smoky Mountains National Park, Tennessee.

Elevation, in feet	No. of species, subspecies and varieties of ants	
	In grassy areas	In all areas
1000–2000	35	64
2000–3000	28	58
3000–4000	14	44
4000–5000	9	28
5000–6000	4	10
6000–	0	2

observed by consulting Table 1. At extremely high elevation, such as at Indian Gap, Newfound Gap and Clingmans Dome, species are few, nests scarce and colonies small. On Mt. Le Conte only two species were collected, and they rather infrequently. On the grassy slopes of the lower elevations ants thrive. From a single, small, well-drained, rocky, south-facing slope near Gatlinburg a total of 22 different species, subspecies and varieties has been collected. Hundreds of colonies of some of them are present, and I have yet to remove the first stone which does not conceal a nest of some ant.

Mound Nests.—Mound nests are present in considerable quantities except at very high elevations. There are relatively few of the large impressive earthen and detritus domes, such as those of the Allegheny mound-builder *(Formica exsectoides)*, although some of these are present; but the smaller mounds of the smaller ants, such as those of *Lasius*, *Pheidole* and *Dorymyrmex*, are in some places remarkably abundant. The proportional size of mound to mound-building ant is still much the same; that is, the smaller species construct smaller mounds and the larger ones larger mounds. Dennis (1938, p. 270) makes the following statement concerning mounds: "One very interesting fact brought out in the collecting is the scarcity of ant mounds in Tennessee. In five years of collecting only one small mound was found." He attempted to explain this "scarcity" by stating that "the soil is warmed to such a depth that mounds are unnecessary *(sic!)* for incubation of the brood," and that "the state as a whole is well drained." (Dennis, *loc. cit.*). But there are probably more ant mounds in the desert and semidesert regions of the United States than in any other region, and in those as a whole the soil is warmed to a sufficient depth for brood incubation and also is for the most part exceptionally well drained. I once counted more than 400 large domed mounds of sand in a quarter-mile-square quadrat in the Mojave Desert of California. I have records of nearly 200 mound nests from the Park—those from which collections have been made. Hundreds of crater mounds (which, however, do not possess chambers) of *Dorymyrmex pyramicus* var. *flavus* are scattered over very sandy abandoned land in the Park near Line Springs. Mention has already been made of the scarcity of ant mounds at high elevations. Drainage in such places, however, is considerably poorer than at lower levels and the

soils are more acid and more sterile. Also, the soil is not warmed to as great a depth as at lower elevations.

Dennis (1938, p. 271) further expostulates: "for this reason the ants are not often forced out by the water table coming to the surface as it does in some of the low poorly drained prairie regions. Ants in regions that are flooded several times each summer get away from the water by building mounds into which they can move when their galleries are flooded." These are assumptions with which I am unable to agree. Apparently the mound-building pattern is inherent to the ant in the germ plasm. It is not at all a matter of the ant's taking advantage of an instinct to "get away" from some destructive force. The mound-building ants seem to construct their mounds regardless of environmental conditions. This may be easily substantiated by keeping a colony of mound-builders under a variety of laboratory conditions. The mound *will* be constructed if there is anything available which may be used for it.

The domed mound seems to afford a space where aeration and incubation are possible. We know that ants do very frequently move the brood back and forth from mound chambers to subterranean levels. So far, we can only surmise at the mechanism involved. I have yet to see an area inhabited permanently by ants which is so poorly drained that the water table comes to the surface several times each summer with ensuing flooding.

Slope Gradient and Exposure.—Dennis (1938, p. 271) writes that "ants are scarce on the slopes of the mountains." I found this essentially to be true where the slopes were steep. In places of less steep gradient colonies were frequently abundant provided the elevation were not more than about 3,000 feet. Steep slopes are susceptible to sheet erosion during periods of heavy rainfall. The run-off is great, the penetration is slight and the soil and stones are subjected to the resultant pressure. Slope exposure in the mountains is very important in respect to insolation which affects local ant distribution. Ants are relatively few on north-facing slopes, but they abound on southern and eastern exposures. On south-facing and east-facing slopes the ants are furnished with warm soil and air temperatures early in the day, and even though these slopes are shaded in the afternoon they retain a sufficient amount of heat to sustain normal ant activity until sunset. On north-facing and west-facing slopes the morning hours are too cool for much activity, while the afternoon hours may be too warm. Dennis (1938, p. 271) found that "the base and the tops of the mountains have a rather abundant ant fauna," but my studies have indicated strongly that at high elevations (5,000-6,500 feet) ants are few. The distribution of ants in the Park is shown, according to elevation, in Table 1.

Frequently differences in structure of insect communities in mountains are attributed to the selective features of altitude as a factor. Naturally, such attempts at explanation of distribution mask the essential factoral complex, since alitude is a point and not by itself a distinct environmental factor except as perhaps exemplifying atmospheric pressure and as occasionally a physical barrier. It is known that such differences in pressure as occur in mountains of

the type under discussion are inconsequential in their effects upon insect distribution. Altitude, from an ecologic standpoint, is rather an expression of a complexity of factors—rainfall, temperature, humidity and the like—which conditions the habitat for the establishment and continuance of plant and animal populations. Thus a difference in a thousand feet of altitude and the variance in climatic and edaphic factors between two places will be reflected by the biota. One of these habitats may be in the fog belt, the other not; one may have a wet acid soil heavily carpeted with moss, the other a dry well aerated soil with only scattered herbs and shrubs in the understory. So the differences in altitude are important in that they show the effects of the environmental factors.

A complex group of factors—climatic, edaphic and biotic—governs the distribution of ants as well as all other organisms. So intimately bound together are these factors that one cannot assign a single one of them as being instrumental above all others as the determinant. However, it is possible to recognize a single factor as being outstandingly important and as being a controlling force because of the effects of other activating factors upon it; and it, in turn, reacts upon the others. Hence there is ever a dynamic interrelationship.

One of the important factors governing partially distribution of some ant species is the nature of the terrain. Slope gradient and direction have been mentioned already. Some species nest only beneath stones, and hence are found only in rocky habitats. Others seem to require logs for nesting sites. Many frequent plant parts only. Most of the remainder colonize the naked soil and usually construct mounds of either the crater or dome types. There is a tendency for some species which inhabit logs to extend their range from a single area to others where logs of the proper condition are present. Thus, *Aphaenogaster fulva aquia* var. *picea*, which is preeminently a log-dwelling ant, ranges from 1,600 feet to more than 5,000 feet elevation. It will, however, nest in the soil beneath stones even when logs are in its habitat, but only apparently as a result of population pressure. There is also the propensity of a few species which normally nest in the soil under stones to construct earthen mounds over their nests where stones are scarce or absent. *Lasius niger* var. *americanus* is one of this group. Lists of species illustrating this type of distribution are presented later in this paper.

Temperature and Moisture as Affecting the Ants.—Temperature and moisture are so intimately connected that it is probably impossible, under natural conditions, to recognize their independent action. Many mountain ants are rather closely restricted to shady and hence cool habitats; but such places are usually also more moist. Thus we can assign neither one nor the other factor as being the controlling one. Acting together they influence ant distribution, vegetation and the edaphic conditions. Ants which abound in sunny places are usually offered also a rather dry and warm soil. Which, if any, is the controlling factor? We are unable to say. The forces are well knit into a unit. Such ants are called inhabitants of "open" situations. It is known, however, that many ants are sensitive to changes in moisture, particularly

those dwellers of wet woods where moisture under normal conditions is constantly abundant. Talbot (1934, p. 438) studied distribution of ants in the Chicago region and states that "from distribution studies it seemed probable that toleration or lack of toleration to extremes of dryness is one of the important differentiating factors in the distribution of species, allowing some forms to penetrate into places of low relative humidity where others are excluded. To test this observation experimentally six species of the genus *Formica* were subjected to controlled conditions of dryness. It was found that those living in the drier places were more resistant to dryness than those living where the moisture supply is more constant. For species of *Lasius* no such differentiation to dryness could be found. These ants do not forage on hot days and so do not face extremes to the extent that the *Formica* ants do."

Some ants will migrate after even relatively slight desiccation of their habitats. Here again there may be a close connection with temperature conditions. Actually it is the microhabitat of the colony and the factors affecting it that are of prime importance for the existence and survival of the ants. It is the small niche in a larger habitat. The conditions affecting the log are the important ones for log-dwelling ants; those affecting a particular portion of the soil for the soil inhabitants, etc. Thus, species which can endure a wide latitude of conditions and changes are those with the higher survival values. The great abundance of some ants in the Park may be attributed to this plasticity in their environment.

Distribution of ants according to nesting sites.—A number of species in the Park nests within logs in various stages of decomposition. These are as follows:

Proceratium croceum
Leptothorax longispinosus
Aphaenogaster lamellidens
A. lamellidens var. *nigripes*
A. fulva
A. fulva aquia
A. fulva aquia var. *picea*
A. tennesseensis
Crematogaster ashmeadi
C. lineolata
Monomorium minimum
Stenamma brevicorne diecki var. *impressum*
Strumigenys creightoni
Prenolepis parvula
Camponotus castaneus
Camponotus herculeanus pennsylvanicus
C. herculeanus pennsylvanicus var. *ferrugineus*
Lasius umbratus speculiventris

Some species live beneath the bark of logs. They are the following ones:

Euponera gilva
Ponera coarctata pennsylvanica
Aphaenogaster fulva
Crematogaster laeviuscula
A. lineolata
C. ashmeadi
Tapinoma sessile
Lasius niger var. *americanus*
L. niger var. *neoniger*
Camponotus caryae

Several species live in the soil beneath logs. These are:

Ponera trigona var. *opacior*
Ponera coarctata pennsylvanica
Aphaenogaster fulva
Monomorium minimum
Solenopsis molesta
Tapinoma sessile
Prenolepis imparis var. *testacea*
P. parvula
Brachymyrmex heeri depilis—under old roots, etc.
Lasius niger var. *neoniger*
L. niger var. *americanus*
L. flavus nearcticus
L. brevicornis—under old roots, etc.
Formica fusca
Camponotus castaneus

A few ants construct their nests under bark of standing dead trees. They are as follows:

Lasius niger var. *americanus*
Camponotus caryae
C. caryae var. *pardus*
C. caryae var. *decipiens*

A small number of species frequently nests beneath moss on logs and the soil. These are:

Myrmecina graminicola americana
Stenamma brevicorne diecki var. *impressum*
Myrmica scabrinodis lobicornis var. *fracticornis*

Beneath the dry peat crust on heath balds have been found nests of *Leptothorax fortinodis* and *Formica fusca* var. *subaenescens;* while under a pile of leaves on the forest floor I observed a colony of *F. sanguinea subintegra.*

A few species nest in the ground without any accessory covers such as stones or logs. These are as follows:

Stigmatomma pallipes
Leptothorax curvispinosus
L. pergandei
Dolichoderus taschenbergi var. *atterima*—base of grass clumps.
D. mariae—base of grass clumps.
D. plagiatus
Formica fusca var. *subaenescens*
F. pallide-fulva schaufussi var. *nitidiventris*

Some species build nests with mounds which may be classified as rudimentaty mounds, craters and domes. They are as follows:

Aphaenogaster treatae—rudimentary
Trachymyrmex septentrionalis obscurior var. *seminole*—rudimentary
Formica fusca var. *subsericea*—earthen "beds"
F. lecontei—earthen "beds"
F. habrogyna—partial banking with detritus
Pheidole vinelandica—crater
Dorymyrmex pyramicus—crater
D. pyramicus var. *flavus*—crater
Prenolepis parvula—crater
Pheidole morrisi—dome
P. dentata var. *commutata*—dome
Lasius niger var. *americanus*—dome
Formica fusca var. *subsericea*—dome
F. exsectoides—dome

A few species build their nests in twigs, nuts, stems and the like. These are:

Leptothorax curvispinosus
L. longispinosus
L. fortinodis

By far the greatest number of ant colonies in the Park are in the soil beneath stones. A list of these comprises 60 different species, subspecies and varieties, but would require too much space to itemize.

Thirty-one kinds of ants have been collected in moist shady woods, and about the same number (32) in open woods; while 35 were found in bright open places.

Plant and vegetational environments.—Both the plant and vegetational environments of the mountain ants are exceedingly important. The plants provide some species of ants with food, directly with seeds which are eaten by ants of the genus *Pheidole,* or indirectly by affording food for plant lice whose exudates the ants devour. I have found nests of *Pheidole* in every grassy area in the Park. Plants may give ants nesting sites of various kinds. Protection from the intensity of radiant energy, rapid desiccation, etc. by the plant cover is evident. The vegetation is affected and conditioned by climatic, physiographic and even biotic factors of the environment, and it in turn

provides and affects its own and the ants' habitat. Thus the vegetation type of an area reflects the nature of the area—the kind and condition of the soil, the amount and distribution of rainfall, the temperatures, etc. It may produce a desirable habitat for some ants and an undesirable one for others. The conditions may be such that an unfavorable habitat for all ants is formed. In this way a vegetation type, a plant community, may be and often is an indicator of the ant community found there. As an example, nests of *Brachymyrmex heeri* var. *depilis* have been observed on heath balds in various parts of the Park. The heath bald vegetation reflects the nature of the habitat of both plant and ant communities. Among other things it provides directly a certain height and density of cover for the soil. A vegetation type may, therefore, have an appreciable effect upon the distribution of ants by affording a definite kind of habitat for those species which can utilize it. It may, of course, provide intrinsically a number of microhabitats which will further distribute the ants.

It is not my intention to discuss fully at this point the relationship which the distribution of ant communities bears to that of the larger and more complex plant communities—the vegetation types. The degree of intensity of this coaction may be ascertained by consulting the discussion appended to the study of the plant-ant communities presented later in this paper. Necessarily, the interpretation must be a broad one because of great community complexity. It is sufficient to summarize these paragraphs by stating that there is a distinct habitat selection propensity exhibited by most ant species, and that the vegetation is distinctly a vital part of the ants' environment.

Distribution of Ants in Vegetation Types

The vegetation of the Park is primarily forest, and plant aggregations without trees are few. These exceptions are the old fields and meadows, the results of man's pressure, and the few small areas dominated by shrubs and herbs—such places as heath and grassy balds.

Vegetation types and their ant inhabitants.—There are three major groups of forest complexes in the Park: (1) spruce-fir, at high elevations; (2) cove hardwoods, in the valleys; and (3) oak-pine, on the drier leads and slopes mostly at lower elevations. A number of collecting stations was selected in various forest types within the three major complexes and in the heath balds and grassy areas in an endeavor to ascertain how great is the correlation between the distribution of ant communities and that of the plant communities represented at the selected stations. These are as follows:

Spruce-fir complex
- Red spruce forest-type (4,950 ft.)
- Mixed spruce-fir forest-type (5,250 ft.)
- Southern balsam fir forest-type (6,500 ft.)

Cove hardwoods complex
- Subalpine beech gap forest-type (4,717 ft.)
- Hemlock ridge forest-type (3,500 ft.)
- Mixed cove hardwoods forest-type (1,800-3,000 ft.)
- Buckeye-basswood forest-type (4,000 ft.)

Oak-pine complex
- Oak-pine forest-type (1,600-3,200 ft.)
- Pine-heath forest-type (3,800 ft.)

Heath bald

Grassland

The various forest-types and other plant communities itemized are discussed individually in the following pages. especially in so far as their ant fauna is concerned.

Red spruce forest-type.—This is dominated by red spruce *(Picea rubens)* and is the most important type of the spruce-fir complex. "This formation which is frequently spoken of as Canadian or subalpine, is relatively homogeneous. The number of species which enter into its composition and the number of forest types formed are relatively few. The formation in the Smokies is distinguished from examples of it in the north by a rather large number of species which are endemic to the southern mountains. This is true of about 25 per cent of the woody species. The definitely northern nature of this formation is evidenced by the fact that about 60 per cent of the woody plants extend into the northeastern United States, or into Canada." (Cain *et al.*, 1937, p. 26).

Fig. 1. Red spruce forest-type. Photo by S. A. Cain.

In the Park spruce is most widely dominant in the lower part of the Canadian belt which extends from an elevation of about 4,000 feet to the mountain tops. Exposure and other topographic features chiefly determine the lower limits of dominance by spruce. In a station in the Greenbrier-Brushy Mountain region, Cain *et al.* (1937, p. 26) found that spruce constituted 90 per cent of the basal area of the stand; red maple 4 per cent; and hemlock, beech and shadberry together 5 per cent. Mountain holly, southern balsam fir, yellow birch and sweet birch made up the remaining one per cent.

Fig. 2. Subalpine meadow with spruce-fir forest-type in the background, Indian Gap. Photo by A. C. Cole.

The woody undergrowth is made up largely of *Rhododendron Catawbiense*, which is associated with some *R. maximum, R. carolinianum, Viburnum lantanoides* and *Vaccinium pallidum*. Other low shrubs are included in the vegetation. Herbaceous species are very scarce under the dense canopy of rhododendron, and most of them are in places where there is a greater abundance of deciduous trees.

This forest-type, which lies mostly above 5,000 feet, is in a climate distinctly different from that of the lower mountain slopes. "Precipitation is greater and more frequent, humidity is higher and fogs and cloudiness are common. The temperatures are generally lower, especially within the forest, and show less daily fluctuations." (Cain *et al.*, 1937, p. 27). The soils are cool and wet, with accumulations of raw humus, and are rocky, shallow and generally not rich.

Ants were scarce, colonies of only three kinds being found. None is limited to the vegetation type. *Aphaenogaster fulva aquia* var. *picea* was best represented, but a number of colonies of *Stenamma brevicorne diecki* var. *impressum* was also present. The ants of this vegetation type nest in the soil beneath stones or in rotting logs.

Mixed spruce-fir forest-type.—This type has nearly an equal mixture of red spruce and southern balsam fir. It is well represented at Indian Gap, near Newfound Gap, at an elevation of 5,250 feet. The stands are not particularly dense but the trees reach a fair height and breadth, and hence the forest floor is rather heavily shaded. The soil is very moist as are the many large decaying

logs strewn over the ground, and there is a somewhat general and heavy carpet of moss. Underbrush is exceedingly sparse and is confined chiefly to the more open spaces. Grassy openings, which are not a natural feature of the forest, are evident in a few places.

In this habitat the primitive insects *Japyx* and *Campodea* (Thysanura) are rather prevalent under rocks in the wet soil. The salamander, *Plethodon jordani,* is very abundant beneath rocks and wet logs. The entire area gives the impression of primordial nature. Only six different kinds of ants were found, and two of these were limited to the forest-type. *Stenamma brevicorne diecki* var. *impressum* and *Aphaenogaster fulva aquia* var. *picea* were the most common.

Southern Balsam-fir forest-type.—Forests dominated by southern balsam fir *(Abies Fraseri)* are generally found at high elevations on poor quality soils. The trees are usually small, crowded and rather stunted since the stand is very dense. At places many dead trees remain standing, and, as the ground is strewn with logs, decomposition apparently takes place very slowly. Over the soil, logs, rocks and even up the tree trunks is a dense carpet of moss. The forest is dark and damp. In the denser stands undergrowth, other than the moss carpet, is sparse. This forest type is in the upper part of the Canadian zone, above the limits of the red spruce forest-type, and in the Park is well represented at elevations of about 6,500 feet. Only two kinds of ants were found, and both of these are a part of the spruce and the spruce-fir

Fig. 3. Southern balsam fir forest-type. Photo by S. A. Cain.

faunas. *Aphaenogaster fulva aquia* var. *picea* was the more abundant, but even its colonies were scarce and small.

In the spruce-fir complex, then, ants are scarce not only in the number of species but also in the number of colonies and in nest populations. For the most part they live under stones, but a few inhabit tiny nests under the moss carpet and others occupy the wet rotting logs on the forest floor. All the ants are boreal types which range also into Canada and into high elevations of the Rocky Mountains, and each is limited in its distribution by the ecological conditions typical of this kind of habitat.

Fig. 4. Supalpine beech gap forest-type. Photo by S. A. Cain.

Subalpine beech gap forest-type.—An example of this type occurs in the Brushy Mountain-Greenbrier region at an elevation of 4,717 feet. It consists of an open park-like beech woods with a grassy forest floor. Underbrush is very sparse. "These forests are restricted to small areas in saddles and gaps. Climatic factors play a role. Air currents circulate through the gaps when everywhere else the air is quiet. In the early spring and late winter these trees are frequently clothed with hoarfrost when the adjacent spruce woods are relatively free. Throughout the seasons clouds drift back and forth through these gaps and in the winter the sleet storms are frequently severe." (Cain *et al.*, 1937, pp. 14-15). The soil is well-drained, rich, deep and only slightly acid, and there is no peat, excessive litter or podzolization. Beech dominates and is associated with peawood and red maple. The few remaining trees are of little importance. There are no evergreen species with the exception of one or two herbs. Shrubs are uncommon except for blackberries, but herbs—especially spring annuals—are rather abundant.

Such a habitat affords a suitable domain for ants, except that logs and stones are extremely scarce. But for the few which take advantage of every stone and log available, the ants are dependent upon the relatively unprotected forest floor for nesting. As the result, there is a number of small earthen mounds in open areas between the grass. On the whole, however, colonies are scarce although quite populous. The species are those which would be expected to colonize such a habitat—species of *Lasius, Prenolepis* and *Crematogaster*. A total of seven different kinds of ants representing seven different genera was found, and none of these was restricted to the vegetation type. *Crematogaster lineolata* and *Lasius niger* var. *neoniger* were the most common occupants.

Hemlock ridge forest-type.—In this type, which occurs usually between 3,500 and 4,000 feet elevation, hemlock *(Tsuga canadensis)* dominates. The stand is said to be pure even though several other species may be associated with it, including red maple, yellow birch, Fraser's magnolia and peawood. The mature hemlocks reach an average height of about 125 feet. Then there is an understory of plants dominated by rhododendron *(Rhododendron maximum)* and laurel *(Kalmia latifolia)*, which together shade about 80 per cent of the ground. *Rhododendron* is much more abundant than *Kalmia*. Especially in small openings, dog hobble *(Leucothoe catesbei)*, blackberry *(Rhubus canadensis)* and elderberry *(Sambucus pubens)* are scattered. Undergrowth is practically absent in such heavy stands of hemlock and rhododendron. The soil is rather thin and has been well leached, and there is an accumulation of a peaty layer. Beneath the peat is a sterile layer called the podzol which has resulted from pronounced leaching. Under this is a richer layer containing the nutritive materials for the plants.

Eleven kinds of ants representing nine different genera were collected. Of these only a single species *(Sysphincta pergandei)* was restricted to the vegetation type, and it was represented by only a single individual. The most common ant of the hemlock ridge type was *Aphaenogaster fulva aquia* var. *picea*.

Mixed cove hardwoods forest-type.—This "name is applied to an extensive and heterogeneous forest found in the mountain valleys and on the lower slopes. Some dozen or more species of trees may be locally dominant or codominant. In addition to these species, perhaps 25 other tree species are rather common associates. The cove hardwoods grade into the spruce-fir formation above and into the oak-pine complex on the drier ridges and foothills. These woods can be thought of as lying in long, more or less narrow, finger-like strips along all the numerous branches of the drainage systems of the mountains." (Cain *et al.*, 1937, p. 22).

In a plot of cove hardwoods in the Greenbrier-Brushy Mountain region the five most important tree species are hemlock, buckeye, sugar maple, basswood and yellow birch; and the remaining species are white ash, peawood, black walnut, chestnut, Fraser's magnolia, beech, yellow poplar, red spruce (at an unusually low altitude for it), mountain holly and witch hazel. There are about 33 species of herbaceous spring flora. In the summer there is a series of shade-tolerant herbs. The soils, "although rocky, are usually relatively

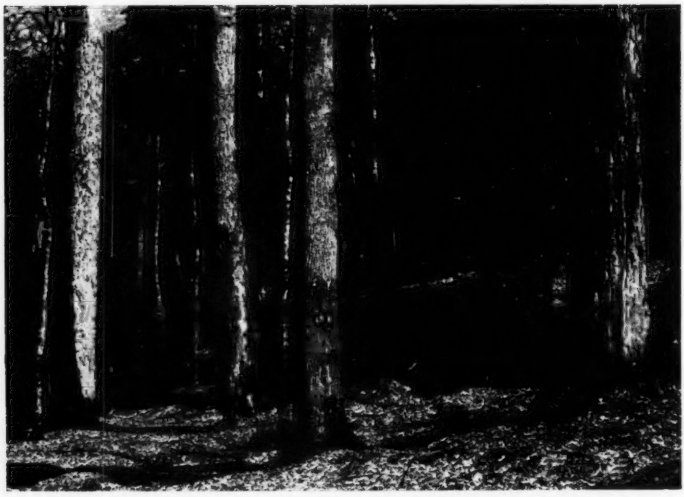


Fig. 5. Mixed cove hardwoods forest-type. Photo by S. A. Cain.

deep, rich in raw humus and nutrients, of good texture and moisture. Their acidity is not high, raw peat does not accumulate, podzolization is absent or slight, and aeration is good. Climatic conditions are not extreme and, generally speaking, all factors are favorable for a luxuriant growth." (Cain *et al.*, 1937, p. 23).

Thirty-nine different kinds of ants were collected in this forest type. Nineteen of these were limited to the mixed cove hardwoods, the remainder being represented in one or more other vegetation types. The most abundant ants were *Aphaenogaster fulva aquia, Crematogaster lineolata, Camponotus castaneus americanus, Formica fusca* var. *subaenescens* and *Prenolepis parvula.* None of the ants limited to this type was particularly common in it.

Buckeye-basswood forest-type.—This forest-type occurs in a great many valleys of the Park, although the stands are small in area. Evergreen trees and shrubs are absent. The dominants are usually yellow buckeye and basswood, and these are associated with a few other deciduous trees. Especially in the spring there is a luxuriant growth of herbs and mosses. The rocks and boulders are everywhere covered with moss. The soil is damp, well-aerated and rich in humus. For the most part, logs are few, and the ants usually nest beneath the mat of moss or occasionally under stones. This forest-type is decidedly not a favorable habitat for ants, and only a few of the more moisture-tolerant species are evident. Only five different kinds of ants were found. Of these but one was limited to the type, and it was scarce. Abundant was *Aphaenogaster fulva aquia* var. *picea,* which is represented also in seven other vegetation types in the Park. *Myrmecina graminicola americana* was a promi-

nent ant and was nearly as well represented as *A. picea.* Colonies of *Myrmica scabrinodis lobicornis* var. *fracticornis* were rather scarce as were those of *Lasius umbratus speculiventris.*

Oak-pine forest-type.—The oak-pine forest-type occurs at various places in the Park, and is well represented at lower elevations on the dry slopes of Brushy Mountain, below the limits of pine-heath. There *Pinus rigida* and *P. pungens* are associated with *Quercus montana* and *Q. coccinea* in dry open stands with little underbrush. The pine has entered after burning. The soil is well drained and the surface well lighted, making for a warm dry soil during the growing season. Such a habitat is rather well suited to the establishment of ants which favor dry well lighted places. The ants are rather abundant both in species and number of colonies, and the nests are well populated. A total of 25 kinds was collected. All but 3 of these were found in one or more of the other vegetation types, and none of these three was represented by numerous colonies. The most abundant colonies were those of *Crematogaster lineolata* and *Formica exsectoides.*

Pine-heath forest type.—The term "pine-heath" is applied to pine woods with a high coverage of heath shrubs in the understory. Pine-heath is rather widely distributed in North America, and it is plentiful in the Coastal Plain region, especially in the pine barrens of New Jersey. One of the best examples of pine-heath in the Park is at 3,800 feet elevation on Brushy Mountain. There the dominant tree is scrub pine *(Pinus rigida)* in an almost pure stand;

Fig. 6. Health bald and pine-heath. Photo copyright, Thompsons, Knoxville, Tenn.

but throughout the stand occur a few trees of red maple, sour gum, table-mountain pine, sassafras and a few chestnut sprouts. The shrub layer of pine-heath is usually dominated by mountain laurel, as it is at the station mentioned. Other shrubs are rosebay, lowbush blueberry, pale blueberry, huckleberry, fetterbush, chokeberry and greenbrier. Under the dense shrub layer is a carpet of teaberry, coltsfoot and trailing arbutus. The only abundant herbs are groundpine, bracken fern and a broomsedge grass.

Typical pine-heath is usually found between 3,000 and 4,500 feet elevation on south to southwest exposures. Due to their south exposure the pine woods receive the direct rays of the sun. This results in several relatively extreme habitat conditions: the temperatures are high and the temperature extremes are great (daily and diurnal ranges); the air is dry and the evaporation high. The soil dries out and the temperature of the surface layers may sometimes reach well over 100 degrees. As a result of the dry, warm condition of the soil, and good aeration, the accumulation of humus is slow and weak, and brown, fibrous, moist peat never accumulates. Under the pines, especially on steep slopes, there may be some sheet erosion. Altogether, the habitat factors act to produce a thin, coarse, sterile, rocky soil, which, in the main, is not favorable to the growth of anything but pine. (Cain *et al.*, 1937, p. 21).

Such an area is distinctly favorable for habitation by ants, and as would be expected, both species and colonies were abundant. Rocks are usually plentiful and old logs lie here and there on the ground. Of the 24 kinds of ants collected, only a single species *(Euponera gilva)* was limited to the vegetation, and only a single nest of this ant was found. Most numerous were colonies of *Crematogaster lineolata* and *Lasius brevicornis*.

Old-field pine.—In Cades Cove there is a rather extensive area of old-field pine which consists of a layer of short grass with second-growth pine growing here and there. The pine stand is nowhere dense and the distance between some of the trees is comparatively great. Th soil is everywhere dry and well-drained with the exception of small areas near streams. As a result, the habitat is favorable for occupancy by an extensive number of ant colonies. Rocks are scattered about on the ground, and these are used as nesting sites by many species. Also, the nature of the soil favors mound development by a few forms. The ant fauna consists of two types: that which inhabits the dry open soil, and that which invades the moist areas. The ants of the dry areas were *Ponera trigona opacior, Eciton nigrescens, Pheidole vinelandica, P. morrisi, Crematogaster lineolata, Tapinoma sessile, Formica pallide-fulva schaufussi, Lasius niger* var. *americanus* and *Prenolepis parvula*. Of this group *P. vinelandica, C. lineolata* and *P. parvula* were most numerous. *Stigmatomma pallipes, Aphaenogaster treatae, A. fulva aquia* var. *picea, A. texana* var. *furvescens, Pheidole dentata* var. *commutata, T. sessile, Camponotus castaneus* var. *americanus, F. pallide-fulva* var. *succinea, F. pallide-fulva schaufussi* var. *dolosa, F. pallide-fulva nitidiventris* var. *fuscata* and *P. parvula* were represented by colonies in the moist area. Of this number, nests of *A. treatae, P. dentata* var. *commutata,* and *C. castaneus americanus* were most abundant. Eighteen different kinds of ants were represented in this vegetation type. Only two of these were restricted to the type, however, and both of them were rather scarce.

Second-growth pine.—At 2,000 feet elevation, on Cove Mountain, is a stand of second-growth pine which has resulted from past lumbering activities. *Pinus echinata, P. rigida* and *P. virginiana* are represented. The open stand of trees and the scant undergrowth make for a rather warm, dry, partially shaded soil, and ant colonies were numerous. Twenty-two species, subspecies and varieties of ants were collected from the area. Best represented were *Pheidole dentata* var. *commutata, Prenolepis parvula, Stigmatomma pallipes* and *Aphaenogaster treatae.* Only one kind of ant, *Crematogaster minutissima missouriensis,* was limited to the area, and it was rare.

Fig. 7. Heath bald on the Chimney Tops. Photo by A. C. Cole.

Heath balds.—These are dense communities of shrubs dominated by plants of the heath family. The growth is low in the most exposed places, especially those with coarse soil. "There do not seem to be any species which are peculiar to the balds, although many of the shrubs occur in abundance only there." (Cain *et al.*, 1937, p. 13) Practically no herbs grow because of the very dense shade. The origin of the balds is as yet unknown, and it is debatable whether they have resulted naturally or whether they have been artificially induced, as by fire. The majority of balds in the Park occupies narrow leads with steep slopes, and the bald vegetation is usually extensive on one slope and along the top of the lead but scant or absent on the other slope. Most of the bald vegetation is on slopes with south or west exposures. The most abundant plants are sand myrtle, mountain laurel and rhododendron.

There is a pronounced accumulation of peat in various stages of decomposition on the soil surface. "In places where the soil becomes driest, the accumu-

lation of brown fibrous peat may be shallow or missing. In its place occurs a thin crust of peaty material which is covered by lichens. The first horizon encountered (in the inorganic soil) is the sterile, well-leached podzol region. This layer is not only poor in nutrients, but it is also the driest layer in the profile." (Cain *et al.*, 1937, pp. 17-18). In some places there is a thin layer of "hard-pan" just beneath the podzol horizon. The peat and leached layers are highly acid. Rainfall is abundant and frequent; there is a high atmospheric humidity and cool to cold temperatures. When the soil is waterlogged it is cold and its aeration is very poor.

Heath balds at several locations in the Park were studied. No ants were found nesting in the waterlogged areas of the heath balds, where the soil conditions were far too unfavorable for colonization. Most nests were beneath stones lying in the thin dry peaty crust, and in such places the colonies were rather abundant. A few ants had constructed nests beneath this dry layer, having apparently entered through some rupture in the surface. The nest galleries and chambers extended rather deeply into the soil—through the podzol region and into the enriched zone. Colonies of several of the ants were very populous. Eight different kinds of ants were collected on heath balds. Although none of them was restricted to the balds, two constituted the most representative types and were found on all heath balds in the Park. These were *Lasius brevicornis* and *Brachymyrmex heeri depilis*, and both were represented by numerous colonies. The only other vegetation type in which they were found was pine-heath, where they were definitely less abundant. Colonies of *Formica fusca* var. *subaenescens* were numerous on all the heath balds, and since these ants forage in the open while *L. brevicornis* and *B. heeri depilis* are completely subterranean in all their activities, they were the most conspicuous feature of the heath bald ant fauna.

Grassy areas.—In many places in the Park, usually at the lower elevations, are lands which were formerly occupied by families who have left the region, and which had been cultivated or grazed. Under such manipulation, the former natural vegetation has been eliminated, and some of the pastures and fields have grown up with, first of all, broomsedge grass. Under the processes of secondary succession the broomsedge grass has become invaded by blackberry, dewberry and greenbrier. Then came light-tolerant trees, such as sumac, black locust, peawood, sassafras and yellow poplar.

After studying various areas of abandoned land in the Park, including those with dense stands of broomsedge grass and other stages in the succession (such as broomsedge grass-brier and old-field poplar), the writer has reached the conclusion that, with the exception of a few species, the ant fauna is rather constant in these places. All are, for the most part, rather level lands with open stands (except for dense covers of broomsedge grass) and dry, well insolated soil. Ant species and colonies are abundant and either nest beneath stones, which are usually plentiful, or construct small mounds of soil; although an occasional species (such as *Camponotus caryae*) nests under bark of standing dead trees which appear later in the succession or in abandoned wasp nests hanging from these trees. Colonies of *Pheidole* are numerous, since nesting conditions are decidedly favorable and seeds for food are plentiful. I encoun-

tered little difference in the qualitative or quantitative populations of the communities representing various stages in the succession, except at extremely high elevations where environmental conditions were unfavorable for colonization by most ants; and such places are few.

There is a large number of grassy hillslopes in the Park, where stones are abundant, the soil well-drained and well-insolated and trees generally absent. Such places, if they are not too steep and sheet erosion is not disastrous, are ideal habitats for a great many species of ants. Southern and eastern exposures are more favorable for occupation by ants, for reasons already indicated in this paper. Nevertheless, there is little qualitative difference in the ant fauna of different slope exposures, in spite of there being usually a marked

Fig. 8. Area of broomsedge grass, Greenbrier Cove. Photo by A. C. Cole.

difference in the quantitative composition. There is frequently a much greater number of species and colonies in these places than on grassy abandoned lands because of the more favorable environmental conditions presented by the slopes. Most of the species nest beneath stones, but a few build small earthen mounds. On grassy slopes, as in the abandoned areas, *Pheidole* is extremely well represented, since the food requisites are present in abundance.

Thirty-seven kinds of ants were collected in grassy areas. Of this group only *Dorymyrmex pyramicus* and its variety *flavus*, *Trachymyrmex septentrionalis obscurior* var. *seminole* and *Iridomyrmex pruinosus* var. *analis* seemed to be limited to the abandoned land. Most numerous of the grassland ants were *Prenolepis parvula*, *Crematogaster lineolata*, *Tapinoma sessile*, *Lasius niger* var. *americanus*, *Pheidole vinelandica*, *P. morrisi*, *Formica pallide-fulva schau-*

fussi and *F. pallide-fulva schaufussi* var. *incerta.* Restricted to the grassy areas were *Eciton carolinensis, Trachymyrmex septentrionalis obscurior* var. *seminole, Leptothorax tennesseensis* (?), *P. dentata, P. tysoni, P. crassicornis, P. dentigula, Dolichoderus mariae, D. taschenbergi* var. *atterima, Dorymyrmex pyramicus, D. pyramicus* var. *flavus, Iridomyrmex pruinosus, I. pruinosus* var. *analis, F. fusca* var. *subsericea, F. lecontei, F. pallide-fulva schaufussi* var. *incerta, Lasius interjectus* and *Prenolepis imparis* var. *pumila.* Some of the grassland ants were also distributed in open woods, as may be observed by consulting Table 1.

Analysis of the data, and the designation of ant communities.—From an analysis of the data on the relation of ants to various vegetation types studied in the Park, the following items became evident: (1) No species[3] of ant was represented in all 10 of the vegetation types. Two were found in 9 different types, 1 in 8, 1 in 7, 2 in 6, 5 in 5, 10 in 4, 7 in 3, 18 in 2 andd 40 were limited each to a single type. (2) As shown in Table 2, grasslands contained the most species, 19, restricted to that type of vegetation; and although the total number of species collected, 37, from this type was two less than that of the mixed cove hardwoods, only 9 species were limited to the latter type. (3) The total number of species collected from all hardwoods types, except the mixed cove hardwoods, and omitting oak-pine, was only little more than half the number found in the mixed type. (4) The pine types (pine heath, oak-pine, old-field pine and second-growth pine) each contained approximately the same number of species. (5) Species of the spruce and fir types were few, and the spruce-fir admixture supported an ant fauna about equal in number of species to the combined species of the two separate types. (6) The buckeye-basswood, beech gap and heath bald types contained only a very few species, and in this respect were similar in quantitative species composition to that of the spruce and fir types.

Replications of ant distribution in vegetation types of various sections of the Park presented a vast amount of data which are available but too voluminous for publication. The highest correlations exist between the qualitative ant populations of grassland areas. For example, a certain group of species including *P. vinelandica, C. lineolata, T. sessile, L. niger* var. *americanus* and *P. parvula* was found in all grassy areas studied. Also, on all heath balds examined were found colonies of *F. fusca* var. *subaenescens, L. brevicornis* and *Brachymyrmex heeri* var. *depilis.*

Further investigations will be necessary in order to establish conclusively the exact relationship between ant and plant communities. Stenotypic ants show the closest association with vegetation types, whereas the eurytypic species exhibit a distribution into various different types. Certain soil, miosture, temperature and light conditions are essential for some ants just as they are for certain plants, and habitat restriction of ants will automatically associate the ants with the plant communities which are likewise so restricted. Thus there

[3] The term "species" is used here in a broad sense to include species, subspecies and varieties, thus eliminating unnecessary repetition of the terms.

TABLE 2.—Distribution of Ants in some Vegetation Types of the Great Smoky Mountains National Park, Tennessee.

	Grass	Mixed cove hardwoods	Buckeye-basswood	Hemlock ridge	Beech gap	Heath bald	Pine-heath	Oak-pine	Old-field pine	Second-growth pine	Balsam fir	Spruce	Spruce-fir
	1	2	3	4	5	6	7	8	9	10	11	12	13
Stigmatoma pallipes		×						×	×	×			
Sysphincta pergandei				×									
Proceratium croceum		×											
Euponera gilva							×						
Ponera trigona opacior	×				×		×	×	×	×			
P. coarctata pennsylvanica		×		×						×			
Eciton nigrescens	×								×				
E. carolinensis	×												
Myrmecina graminicola americana		×	×	×				×					
Solenopsis molesta	×	×					×	×					×
Monomorium minimum	×	×						×		×			
Pheidole morrisi	×								×				
P. vinelandica	×								×				
P. dentata	×												
P. dentata var. *commutata*	×								×				
P. tysoni	×												
P. crassicornis	×												
P. dentigula	×												
Crematogaster lineolata	×	×		×	×	×	×	×	×	×			
C. laeviuscula		×											
C. minutissima missouriensis										×			
C. ashmeadi							×	×					
Stenamma brevicorne diecki impressum												×	×
Aphaenogaster fulva		×					×			×			
A. fulva aquia		×					×			×			
A. fulva aquia picea		×	×	×					×	×	×	×	×
A. lamellidens		×											
A. lamellidens var. *nigripes*		×								×			
A. tennesseensis		×											
A. texana var. *furvescens*									×				
A. texana var. *carolinensis*								×					
A. texana punctithorax		×											
A. treatae	×							×	×	×			
A. treatae var. *harnedi*	×												
Myrmica punctiventris		×						×					
M. scabrinodis lobicornis fracticornis		×	×	×						×			
Leptothorax fortinodis		×				×	×						
L. longispinosus		×		×		×		×					
L. curvispinosus		×					×			×			
L. pergandei								×					
L. tennesseensis	×												
Strumigenys creightoni								×					
Trachymyrmex septentrionalis obscurior seminole	×												
Dolichoderus mariae	×												
D. taschenbergi var. *atterima*	×												

	1	2	3	4	5	6	7	8	9	10	11	12	13
D. plagiatus							×	×					
Dorymyrmex pyramicus	×												
D. pyramicus var. *flavus*	×												
Tapinoma sessile	×	×		×	×	×	×	×	×	×			
Iridomyrmex pruinosus	×												
I. pruinosus var. *analis*	×												
Brachymyrmex heeri depilis						×	×						
Prenolepis imparis		×						×					
P. imparis var. *pumila*	×												
P. imparis var. *testacea*		×											
P. (N.) parvula	×	×			×		×	×	×	×			
Lasius brevicornis						×	×						
L. niger var. *neoniger*	×	×		×	×		×						
L. niger var. *americanus*	×	×					×	×	×	×			
L. flavus nearcticus		×											
L. umbratus mixtus aphidicola		×											
L. umbratus speculiventris		×	×										
L. (A.) interjectus	×												
L. (A.) claviger	×	×								×			
Formica sanguinea aserva													×
F. sanginea subintegra			×										
F. sanginea rubicunda													×
F. exsectoides							×	×					
F. habrogyna	×						×						
F. fusca											×	×	×
F. fusca var. *subsericea*	×												
F. fusca var. *subaenescens*		×			×	×	×			×			
F. lecontei	×												
F. pallide-fulva schaufussi	×						×		×				
F. pallide-fulva schaufussi dolosa	×						×		×	×			
F. pallide-fulva schaufussi incerta	×												
F. pallide-fulva nitidiventris	×	×				×	×	×					
F. pallide-fulva nitidiventris fuscata									×				
F. pallide-fulva var. *succinea*								×	×				
Camponotus castaneus		×											
C. castaneus americanus		×					×	×	×	×			
C. herculeanus pennsylvanicus		×		×				×		×			
C. herculeanus pennsylvanicus ferrugineus		×		×				×		×			
C. caryae		×					×						
C. caryae var. *pardus*		×						×					
C. caryae var. *decipiens*		×											
Totals (86 ants)	37	39	5	11	6	8	24	25	18	22	2	3	6

becomes established a dynamic ant community with a community of plants. Talbot (1934) has discussed the ant and plant community relationships in the Chicago region. She studied the ant-plant make-up of the beach, fore dunes, poplar dunes, mixed oak woods on clay, oak-maple woods on sand, beech-maple climax and prairie. Her ant communities were named from the ants most restricted to each of the plant associes and most characteristic of it. When the same type of analysis is applied to ants of the Park, the results are of little significance since, for the most part, the ants which are restricted to a vegetation type are uncommon in it and hence not actually characteristic of it. For example, in the buckeye-basswood type the ants most restricted to the type are *Lasius umbratus speculiventris* and *Formica sanguinea sub-*

integra; but there were rare ants in the community. Most abundant, and in this respect most characteristic, were *Aphaenogaster fulva aquia* var. *picea* and *Myrmecina graminicola americana.* It is true that each of these two ants occurred in other vegetation types in the Park, separately and together, but not by any means in the abundance in which they were found in the buckeye-basswood community.

A community named for an ant species which was found but once or only periodically has practically no meaning and certainly gives no indication of the community structure which may be dominated by another species. A number of replications would have to be made to determine whether or not the single rare species were representative of the community as occurring in other areas. If it were found in all or in a high percentage of the samples, the use of its name for designating the ant community would be logical. It does not seem advisable, therefore, to name communities of ants in the Park from the ants which are restricted to the communities unless they are also represented in abundance. Instead they are listed as follows, named by the dominant or dominants in the community, which would tend to indicate at least a part of the optimum region of the ecologic amplitude of the dominants:

Red spruce type: *Aphaenogaster fulva aquia* var. *picea* community.

Mixed spruce-fir: *Stenamma brevicorne diecki* var. *impressum—Aphaenogaster fulva aquia* var. *picea* community.

Southern balsam fir: *Aphaenogaster fulva aquia* var. *picea* community.

Subalpine beech gap: *Lasius niger* var. *neoniger—Aphaenogaster fulva aquia* community.

Hemlock ridge: *Aphaenogaster fulva aquia* var. *picea—Camponotus herculeanus pennsylvanicus* var. *ferrugineus* community.

Mixed cove hardwoods: *Aphaenogaster fulva aquia—Camponotus castaneus* var. *americanus* community.

Buckeye-basswood: *Aphaenogaster fulva aquia* var. *picea—Myrmecina graminicola americana* community.

Oak-pine: *Formica exsectoides—Crematogaster lineolata* community.

Pine-heath: *Lasius brevicornis—Crematogaster lineolata* community.

Old-field pine: *Pheidole dentata* var. *commutata—Prenolepis parvula* community.

Second-growth pine: *Stigmatomma pallipes—Aphaenogaster treatae* community.

Heath bald: *Brachymyrmex heeri* var. *depilis—Formica fusca* var. *subaenescens—Lasius brevicornis* community.

Grassland: *Pheidole vinelandica—Lasius niger* var. *americanus* community.

A Systematic Treatment of Ants of the Park

Taxonomic characteristics of Formicidae.—Ants belong to the order Hymenoptera, which includes also the bees and wasps and their relatives. Many parasites of harmful insects are members of this order. The ants belong to a single family, Formicidae, which comprises seven subfamilies, five of which are represented in the Park, as follows: Ponerinae, Dorylinae, Myrmicinae, Dolichoderinae and Formicinae. Ants differ from all other members of the order in that the abdomen is differentiated into two well marked regions --a slender pedicel which is either one- or two-jointed and very mobile, and

a larger thicker terminal portion called the gaster. The gaster, then, is only a part of the abdomen whose fore part connects with the pedicel which is fused with the thorax. The epinotum, which is anterior to the pedicel, is actually the first segment of the abdomen, although it appears to be a part of the thorax. The pedicel, when consisting of but a single joint, is called the

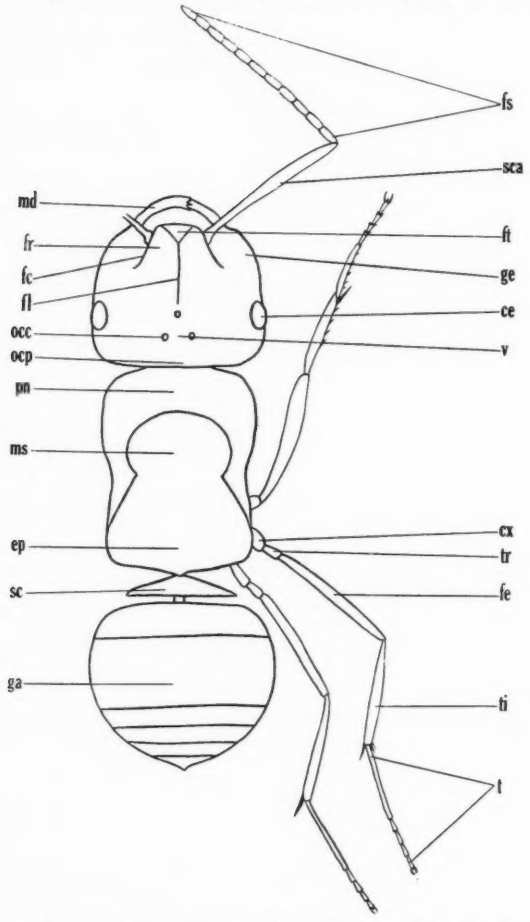


Fig. 9. Dorsal view of a Formicine ant. Md, mandible; fr, frons; fc, frontal carina; fl, frontal suture; occ, ocellus; ocp, occiput; pn, pronotum; ms, mesonotum; ep, epinotum; sc, scale; ga, gaster; fs, funiculus; sca, scape; ft, frontal area; ge, gena; ce, compound eye; v, vertex; cx, coxa; tr, trochanter; fe, femur; ti, tibia; t, tarsus.

petiole; when of two joints, the petiole and postpetiole. When one-jointed, the pedicel usually has a dorsal scale of variable size and shape. The antennae are elbowed, and in the female and worker the first joint of each antenna is greatly elongated. All species are social. Terms of structure, with which the student of ants in the Park should be acquainted are listed in the glossary and are illustrated by figures 9 to 14.

KEY TO THE WORKERS OF THE SUBFAMILIES OF FORMICIDAE IN THE PARK

1. Pedicel distinctly two-jointed 2
   Pedicel not two-jointed 3
2. Frontal carinae very closely approximated, not covering the antennal insertions.... *Dorylinae*
   Frontal carinae covering the antennal insertions ..... *Myrmicinae*
3. Gaster constricted between its first two segments..... *Ponerinae*
   Gaster not constricted 4
4. Gaster with five visible ventral segments; anal orifice terminal, circular and fringed with hairs ..... *Formicinae*
   Gaster with four visible ventral segments; anal orifice ventral, slit-shaped and not fringed with hairs ..... *Dolichoderinae*

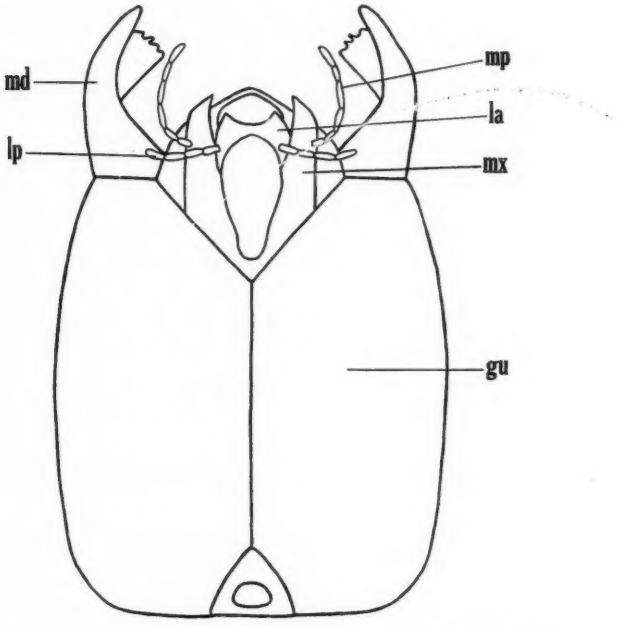


Fig. 10. Ventral view of an ant's head. Md, mandible; lp, labial palp; mp, maxillary palp; la, labium; mx, maxilla; gu, gula.

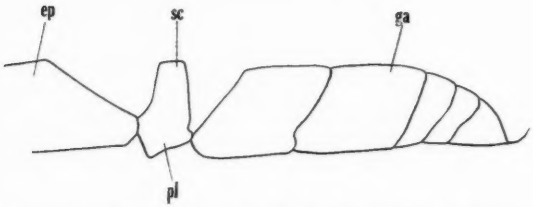


Fig. 11. Lateral view of the abdomen, subfamily Ponerinae. Ep, epinotum; sc, scale; ga, gaster; pl, pedicel.

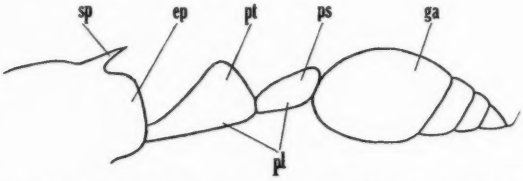


Fig. 12. Lateral view of the abdomen, subfamily Myrmicinae. Sp. epinotal spine; ep, epinotum; pt, petiole; ps, postpetiole; ga, gaster; pl, pedicel.

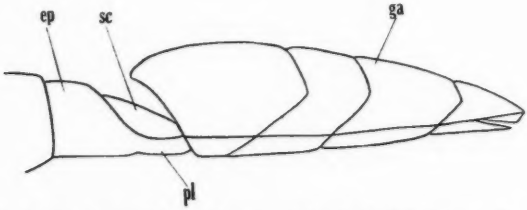


Fig. 13. Lateral view of the abdomen, subfamily Dolichoderinae. Ep, epinotum; sc, scale; ga, gaster; pl, pedicel.

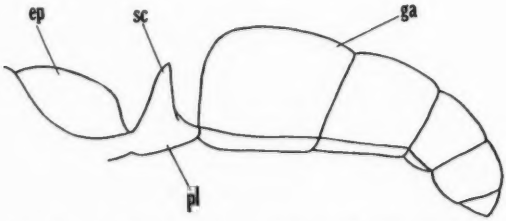


Fig. 14. Lateral view of the abdomen, subfamily Formicinae. Ep, epinotum; sc, scale; ga, gaster; pl, pedicel.

Subfamily PONERINAE

KEY TO THE GENERA OF PONERINAE, FOR DETERMINATION OF THE WORKERS

1. Frontal carinae closely approximated, antennae inserted very near the oral margin, tip of gaster strongly deflected downward 2
   Frontal carinae of a different conformation, tip of gaster not deflected downward.... 3
2. Front of clypeus projecting in the middle, petiole nodiform.....*Sysphincta* Roger
   Clypeus not projecting in the middle, petiole with a scale.....*Proceratium* Roger
3. Mandible long and slender with coarse bidenticulate teeth, anterior border of clypeus dentate, petiole not constricted posteriorly.....*Stigmatomma* Roger
   Not so 4
4. Middle and hind tibiae with a single spur.....*Ponera* Latreille
   Middle and hind tibiae with two spurs .....*Euponera* Forel

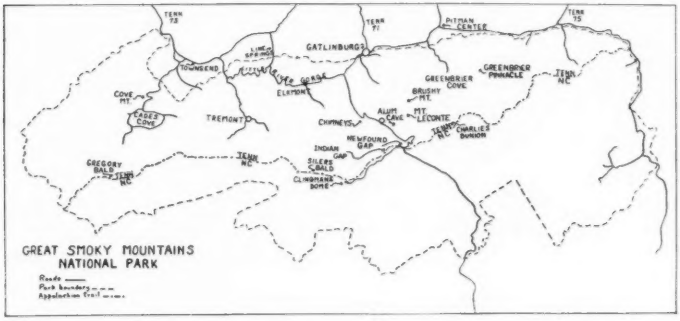


Fig. 15. Map of the Great Smoky Mountains National Park showing the principal Tennessee localities cited in the text.

Genus STIGMATOMMA Roger

Stigmatomma pallipes (Haldeman)

This graceful long reddish brown ant has the head and thorax subopaque and the gaster shining. The clypeus possesses numerous teeth on its anterior margin. The head is somewhat darker than the remainder of the body. The total body length is about 6 mm. *S. pallipes* is the only species of its genus known from the Park.

Distribution.—Greenbrier Cove, 1800 ft.;[4] Cove Mt., 2000 ft.; Cades Cove, 1800 ft. (Talbot, Cole).

S. pallipes is a very primitive ant. It is subterranean in habits and in the Park lives in the rather damp soil of woods, particularly pine at elevations near 2000 feet. It nests usually beneath stones or leaf mold. The elongate workers are timid and sluggish, but have a way of "slinking" into their galleries which demands that the collector be on the alert when hunting for them. The color of the ant very frequently matches that of the soil. Colonies are invariably small, consisting usually of not more than a dozen or so workers. The

[4] All localities in this paper which bear no collector's name are those from which collections were made by the writer.

slender elongate hairy larvae have mouthparts especially adapted for utilizing pieces of insects with which they are fed by the workers. The cocoons are dark brown in color and of an elongate elliptical shape.

The nest consists of one or two openings beneath or beside a stone or under the topmost forest litter. Almost perpendicular galleries connect with small subterranean chambers never far beneath the surface. Sometimes workers may be obtained readily by parting the upper layer of pine duff and sifting a handful of the rich mold lying beneath. These ants are nowhere abundant in the Park but seem to occupy rather circumscribed areas where environmental conditions, particularly moisture and deep shade, are favorable. Colonies were most numerous in second-growth pine woods.

Genus Sysphincta Roger

Sysphincta pergandei Emery

This is a small reddish brown species. The tip of the gaster is strongly deflected downward and somewhat forward. The front of the clypeus projects in the middle and the petiole is without a scale. The head and thorax are subopaque, the petiole is slightly shining and the gaster decidedly shining.

Distribution.—Greenbrier Cove, 3000 ft.

S. pergandei is a rare primitive ant. A solitary worker was found beneath a stone in the hemlock ridge forest-type. There was no evidence of a colony. This species inhabits moist areas, particularly meadows, and lives in nests beneath stones.

Genus Proceratium Roger

Proceratium croceum (Roger)

This rare species, which is the only one known from the Park, is of a ferrugineous color, with sculptured and subopaque head and thorax and shining gaster. The body is densely covered with yellow hair. The body length is about 3.5 mm.

Distribution.—Greenbrier Cove, 1800 ft.

This ant is indeed very rare in the Park, if the number of attempts which have been made to secure it are indicative. A single nest was found in a moss-covered log in a wet densely shaded area of mixed cove hardwoods. The log was well decayed and of such a consistency that it was broken easily with the fingers into pieces each of which was of a firm texture and contained much moisture. Well toward the center of the log, in the more firm core wood, the ants had constructed small galleries and chambers chiefly with longitudinal penetration. In all, the nest covered a length of about 4 inches. It is evident that a collector could easily fail to discover a colony such as this unless he were very careful to examine the entire log. The colony was rather small, being composed of about 30 workers. A few males and females were in the nest (August 4, 1938), and both larvae and cocoons were present. In the surrounding more decayed part of the log was a huge colony of *Aphaenogaster fulva aquia* var. *picea*, which was in no way connected with the *Proceratium* nest. The workers of *P. croceum* are sluggish in their movements.

Genus EUPONERA Forel

Euponera gilva (Roger)

This is the only species of *Euponera* known from the Park. It is about 3 mm. in body length and of a ferrugineous color, with the head and mandibles slightly darker. The antennal scapes are short and do not reach the posterior border of the head. The compound eyes are extremely small. The head is opaque, the thorax less so and rather glabrous, while the sides of the epinotum, the petiole, legs and gaster are shining.

Distribution.—Brushy Mt., 3800 ft.

A single small nest of *E. gilva* was found on a slope of pine-heath beneath the loose bark of a pine log. In the rather moist region between the bark and the wood, which showed no signs of decay, the ants had constructed galleries and wide shallow chambers. Although this nest contained only about 35 individuals, the species is known to have a colony strength of sometimes as many as several hundreds of workers. The nesting site was well shaded by pines. The workers are sluggish in their movements.

Genus PONERA Latreille

KEY TO THE SPECIES OF THE GENUS PONERA IN THE PARK

Petiole in profile rather slender, distinctly narrower dorsally; body slender, light brown to pitchy black in color.....*trigona* var. *opacior* Forel

Petiole in profile rather thick, about the same width dorsally as ventrally, subrectangular; head and thorax densely and coarsely punctate, subopaque.....*coarctata pennsylvanica* Buckley

Ponera trigona var. *opacior* Forel

This slender graceful ant, which ranges in length from 2 to 2.3 mm., varies in color from light brown almost to black. The appendages are paler. The surface of the body is rather glabrous. Hairs are few, being most evident on the dorsal surface of the head and gaster; on the head they are long, on the gaster short. The petiole, in profile, is triangular.

Distribution.—Near Wears Cove, 1700 ft.; Cove Mt., 2000 ft.; Brushy Mt., 3200-3800 ft.; Greenbrier Pinnacle, 3400 ft.; Greenbrier Cove, 1800-3000 ft.; near Gatlinburg, 1500 ft.; Gregory Mt., 2400 ft.

P. trigona var. *opacior* is rather common in the Park, and is apparently far better represented than *P. coarctata pennsylvanica*. It nests in rather open habitats but where the soil contains an appreciable amount of moisture. In such places colonies may be numerous beneath stones or, less often, under logs. Colonies are small and consist of a dozen to twenty or more sluggish workers. The tiny subterranean chambers open to the surface through short perpendicular galleries. I have not seen this ant in dense wet woods.

Ponera coarctata pennsylvanica Buckley

The color of this ant is generally black, but occasional specimens are reddish brown with splotches of black. The clypeus, mandibles, frontal carinae, antennae, legs and tip of the gaster are of yellowish or reddish color. The

head and thorax are subopaque and the petiole and gaster are more shining. This ant is larger than *P. trigona* var. *opacior*, being 3-3.75 mm. in length, and the petiole, in profile, is decidedly rectangular instead of triangular.

Distribution.—Greenbrier Cove, 1800 ft.; Greenbrier Pinnacle, 3200 ft.; Ramsey Cascades, 4200 ft.; Cove Mt., 2000 ft.; Cades Cove (Talbot, Cole); near Gatlinburg (Talbot); Great Smoky Mts. (C. H. Seevers).

My collections indicate that *pennsylvanica* is poorly represented in the ant fauna of the Park. Its habits and type of nest are much the same as those of *opacior*, but the workers appear to be even more apathetic and the colonies occupy more moist places. This ant has been found in the Park only within wet woods in moist deeply shaded soil. The nests were beneath stones or logs or under the loose basal bark of logs.

Subfamily Dorylinae
Genus Eciton Latreille

Key to the Species of the Genus Eciton in the Park

Head, thorax, petiole and postpetiole subopaque.....*nigrescens* (Cresson)
Head, postpetiole and gaster shining; petiole not much longer than broad, subrectangular .....*carolinensis* Emery

Eciton nigrescens (Cresson)

These ants are 3-6 mm. in body length, and vary in color from light reddish brown to very dark brown or black. The head, thorax and petiole are subopaque and heavily sculptured, and the gaster is shining.

Distribution.—Cades Cove, 1800 ft.; near Gatlinburg, 1600 ft.

Two colonies of this species were found. Both were beneath large flat stones, loosely applied to the soil, in open grassy areas. Each colony consisted of thousands of workers, many of which massed for attack when the stone was removed. Deep within the soil the ants occupied large brood-filled chambers constructed around imbedded and partially decayed tree roots. The workers of one colony, upon being disturbed, moved away from the nesting site in long files, each worker carrying one of the brood. The soil, even at chamber level, was dry and firm. The queen was not found in either nest. Always she is very elusive, although of large size compared with her workers. Even before impregnation, while still a virgin female, she is apterous. These ants are carnivorous and feed upon other kinds of ants and other insects.

Eciton carolinensis Emery

This species has the body reddish yellow in color. The head, postpetiole and gaster are shining and the petiole is subrectangular and not distinctly longer than broad. The body length varies from about 2 to 4 mm.

Distribution.—Greenbrier Cove, 1500, 1800 ft.; Greenbrier Cove (Talbot); Cove Mt., 2000 ft.; near Gatlinburg, 1500 ft.

The habits and habitat of this species are very similar to those of *nigrescens*. Four nests were found by the writer, each with a queen, and all were in open grassy and rather dry areas. Two were beneath large flat loosely imbedded

stones, one was under dry moss and the other beneath a board. The colonies were large, each containing thousands of workers. There was considerable evidence in each instance that the *carolinensis* colony had occupied the nest of another kind of ant, probably first of all entering, preying upon and otherwise actively dispelling the tenants. In each nest beneath a stone the single immense queen was in a teeming mass of workers in the stone's impression. The workers were extremely active and pugnacious.

Subfamily Myrmicinae

Key to the Genera of Myrmicinae in the Park

1. Postpetiole articulated to the dorsal surface of the gaster which is flattened dorsally, more convex ventrally and acutely pointed ..... *Crematogaster* Lund
   Postpetiole inserted at the anterior end of the gaster which is of the usual type 2
2. Antennae 6-jointed; head cordiform ..... *Strumigenys* F. Smith
   Antennae with more than 6 joints; head not cordiform 3
3. Antennae 11-jointed, without a distinct club, or with a club consisting of only a single joint; head narrow, with angular occipital lobes; body rough, covered with spines or tubercles ..... *Trachymyrmex* Forel
   Antennal club with several joints, or antennae not 11-jointed 4
4. Antennae 10-jointed, with a 2-jointed club; epinotum unarmed ..... *Solenopsis* Westwood
   Antennal club, when developed, with more than 2 joints 5
5. Posterior margin of clypeus in front of antennal insertions reduced to a mere ridge ..... *Myrmecina* Curtis
   Posterior border of clypeus not thus reduced 6
6. Antennae 11-jointed 7
   Antennae 12-jointed 8
7. Epinotum armed with spines or teeth; clypeus without a pair of ridges projecting forward in the form of teeth ..... *Leptothorax* Mayr
   Epinotum unarmed; clypeus with a pair of ridges which extend forward in the form of teeth ..... *Monomorium* Mayr
8. Soldiers present and much larger than the workers, intermediates absent; antennal club 3-jointed, longer than remainder of funiculus ..... *Pheidole* Westwood
   Soldiers absent, intermediates between the small and large workers; antennal club indistinct or shorter than remainder of funiculus 9
9. Last three antennal joints much shorter than remainder of funiculus and not forming a distinct club 10
   Last three antennal joints forming a distinct club nearly as long as remainder of funiculus ..... *Leptothorax* Mayr.
10. Posterior tibial spurs pectinated ..... *Myrmica* (Latreille) Mayr
    Posterior tibial spurs not pectinated 11
11. Small hypogaeic species with vestigial eyes and two keels on the clypeus ..... *Stenamma* Westwood
    Medium sized species with well developed eyes and no keels on the clypeus; thorax and legs slender ..... *Aphaenogaster* Mayr

Genus Myrmecina Curtis

Myrmecina is a small genus of ants of which there is only one representative known from the Park. With few exceptions, these ants nest under stones or in rotting wood in damp shady forests. Colony populations vary considerably, although most of them are small.

Myrmecina graminicola americana Emery

This small species has a body length of about 3 mm. It is dark reddish

brown in color, with the mandibles, clypeus, appendages and posterior portion of the gaster much lighter. The head, and especially the thorax, petiole and postpetiole, are coarsely sculptured, but the gaster is smooth and shining. The epinotum bears two pairs of spines. The entire body is very hairy.

Distribution.—Greenbrier Cove, 2900, 3000, 3500, 4000 ft.; near Gatlinburg (Talbot); Cades Cove (Talbot).

M. americana is moderately abundant in certain circumscribed regions of the Park. It has been found only in very moist habitats, where it lives in small colonies and constructs little nests in wet rotted hollow twigs, under dense masses of moss on logs on stones and beneath small stones. It was found to be a rather common representative of the meager ant fauna of the buckeye-basswood forest. Many of the colonies consisted of only 12 to 20 workers. The nests are of a very superficial nature and the chambers are generally those natural crevices which may be accessible. The workers are extremely slow of movement.

Genus Monomorium Mayr

There is but a single species of this genus in the Park, in so far as is known. *Monomorium* may best be distinguished from other genera by referring to the characters in the key.

Monomorium minimum (Buckley)

This tiny ant is of a very shining black color, and since it is the only member of its genus known in the Park, it may be recognized easily by this and the key characters.

Distribution.—Wears Cove road, 1700 ft.; Cove Mt., 2000 ft.; Greenbrier Cove, 2900 ft.; near Gatlinburg, 1500 ft.; Gregory Mt., 2100 ft.; Cades Cove, 1800 ft. (Talbot, Cole).

Although being a very common ant in most parts of the eastern United States, *M. minimum* was found at only a few localities in the Park. As a rule, it lives in large colonies generally in the soil beneath stones, although it frequently nests beneath and in logs. It was best represented under stones on the grassy slopes near Gatlinburg, but it was found also in rather open woods. A single colony was discovered in the mixed cove hardwoods at an elevation of 2900 feet. This is the highest place from which it has been taken in the Park, and the colony was unusually small. The little black workers move about very agilely and will quickly attack the collector who disturbs the nest. The colonies contain supernumerary queens, and one nest which I examined possessed 76 of them. Both males and winged females were very abundant in nests near Gatlinburg during the latter half of June, 1939.

Genus Solenopsis Fabr.

The genus may be most easily distinguished from other genera by the characters given in the key to genera. *Solenopsis* is a large genus with many differences in habits and habitats among its numerous species. Since only one species occurs in the Park, a discussion of the genus is omitted.

Solenopsis molesta (Say)

This ant is about 1.3 mm. in body length, of a light tan color with even lighter appendages, smooth and shining and has sparse, rather long hairs.

Distribution.—Greenbrier Cove, 2000 ft.; near Gatlinburg, 1500 ft.; near Tremont, 1700 ft.; Brushy Mt., 4900 ft.; Gregory Mt., 4900 ft.; Greenbrier Pinnacle, 2900 ft.; Newfound Gap, 5045 ft.; Cades Cove (Talbot, Cole).

S. molesta is not particularly common in the Park. It lives in small colonies, either independently beneath stones or wood or as a "thief ant" between the galleries and chambers of other and larger species. Both types of nests were found in the Park. The independent nests consisted of a very few tiny chambers and galleries lying very near the soil surface just beneath the cover of stone or wood. The thieving colonies feed upon the food gathered by the "host" species and are known occasionally even to attack the brood of the other species. Primarily, *molesta* is an inhabitant of dry grassy areas, such as occur near Gatlinburg and Tremont; but a few nests have been found elsewhere in the Park. One was discovered at Newfound Gap beneath a stone in a moist shady forest and another on Greenbrier Pinnacle. The much larger brownish colored females and the black males were found in nests near Gatlinburg during July, 1939.

Genus PHEIDOLE Westwood

This is one of our largest genera of ants, for it consists of a great number of species, many of which are represented in the Park. All nest in dry, open grassy places, under stones, beneath or in logs, or in the open with mounds of soil. The genus is especially interesting because two types of wingless castes are evident—the worker, which is small and normal in conformation, and the soldier, which possesses a huge head and powerful, well developed mandibles, as well as often being very much larger than the worker. These ants are primarily seed-eaters, and it has been suggested that the soldier is the caste responsible for cracking the seeds so that the pieces may be fed to other members of the colony. The workers forage for seeds of various annuals (especially grasses), transport them to their nests and remove the hulls. Then the seeds are stored in some of the nest chambers where they may be utilized as a food supply for the colony, particularly in winter. The workers of some forms attend aphids, and most supplement their diet with dead insects. The colonies are frequently extremely populous, and while some species are sluggish in their movements, others show great alacrity and attack any invader of the nest.

For determination of the various species, subspecies and varieties, the soldier caste is necessary, since the workers do not exhibit adequate structural differences. Besides having this remarkable soldier caste, the ants of this genus may be distinguished form those of other genera by the 3-jointed antennal club which is longer than the remainder of the funiculus.

KEY TO THE SPECIES OF THE GENUS PHEIDOLE FOR IDENTIFICATION OF THE SOLDIERS

1. Antennal scapes distinctly flattened at the base when viewed in profile..... *crassicornis* Emery

Antennal scapes not as above 2
2. Epinotum with very short, blunt or tuberculate spines .....*morrisi* Forel.
Epinotum not as above 3
3. Head elongate, with subparallel sides, for the most part shining throughout.....
.....*tysoni* Forel
Head not strikingly elongate nor with subparalleled sides, only partly shining..... 4
4. Head for the most part finely but thickly punctate throughout; gula, when viewed in profile, with two large, coarse teeth which are easily seen; postpetiole strikingly broader than long, each side very sharply conulate.....*dentigula* M. R. Smith
Not as above 5
5. Antennal scapes short, extending only about half the length of the head.....
.....*vinelandica* Mayr
Antennal scapes longer 6
6. Posterior half of head, dorsum of pro- and mesothorax and dorsum of petiole and postpetiole, smooth and shining.....*dentata* var. *commutata* Mayr
Not as above .....*dentata* Mayr

Pheidole vinelandica Mayr

The soldier varies from light to dark brown in color, with at least the posterior part of the gaster darker. The posterior half of the head and all of the gaster are smooth and shining. The antennal scapes are very short. The body length is about 2.5 mm.

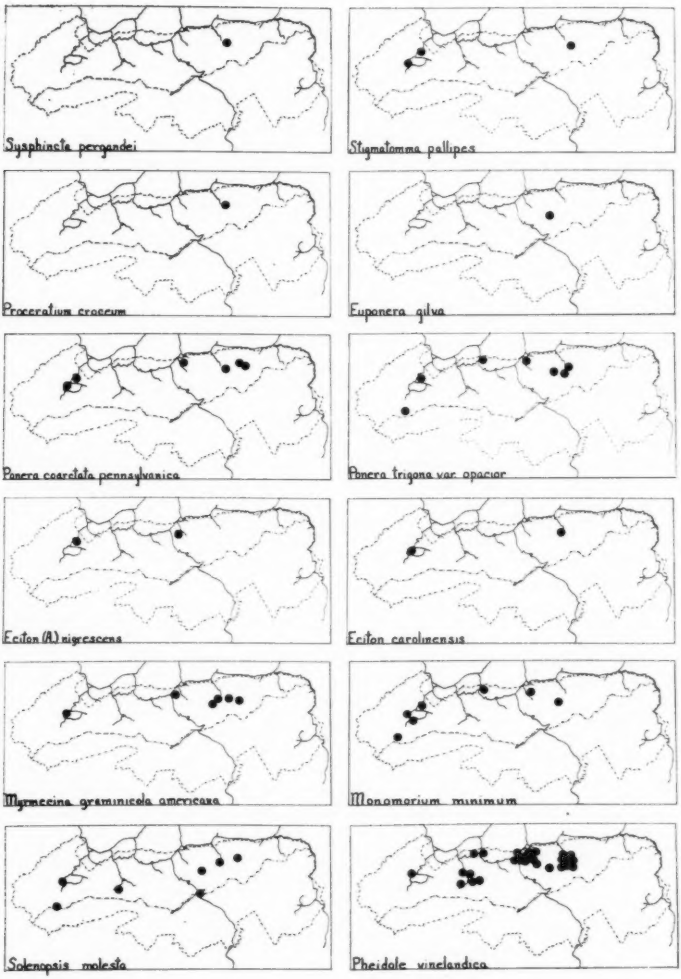
Distribution.—Greenbrier Cove, 1500-2500 ft.; Greenbrier Cove (Talbot); near Gatlinburg, 1500-2000 ft.; Wears Cove road, 1700 ft.; near Tremont, 1700 ft.; Brushy Mt., 2250 ft.; Davenport Gap, 2000 ft.; Cades Cove, 1800 ft.; Little River Gorge, 1565 ft.

This small species is without doubt the most common one of the genus at lower elevations in the Park. It inhabits all the open grassy fields and slopes to elevations of about 2500 feet. It either nests in the ground beneath stones, this being the usual thing, or in subterranean chambers marked on the surface by small crater mounds of fine soil particles. Beneath a stone is a series of lateral galleries and small superficial chambers connected by a very few vertical galleries with several shallow chambers near the soil surface. In the deeper chambers seeds of various grasses and other herbs are stored for food, and even one or more of the superficial chambers in the stone's impression may contain seeds in considerable quantities. Small colonies are the rule, and these may possess as many as approximately 200 workers and soldiers; but usually there are fewer. All castes are slow of movement and very timid, and enter the vertical galleries as soon as the stone has been removed from the nest. The crater type of nest leads, by way of a single vertical gallery, into interconnected chambers in the soil. On a grassy slope near Gatlinburg hundreds of nests were found. Males and virgin females were in these nests June 17, 1939.

Pheidole dentata Mayr

In the soldiers of this species the tips of the antennal scapes extend beyond the posterior margin of the head. The dorsal surface of the pro-and mesothorax and that of the petiole and postpetiole are subopaque. The body is mostly shining, with light to medium brown head and thorax, petiole and postpetiole, and the gaster darker.

PLATE 1


Stigmatomma pallipes
Euponera gilva
Ponera trigona var. opacior
Eciton carolinensis
Monomorium minimum
Pheidole vinelandica

Distribution.—Greenbrier Cove, 1800, 2300 ft.

Several nests of *dentata* were located in fields of broomsedge grass. All were beneath stones and consisted of rather large colonies. The nest chambers were somewhat larger than those of *vinelandica* and extended more deeply into the soil. *P. dentata* is a considerably larger ant than *vinelandica* and is much less sluggish of movement. Several subterranean nest chambers examined contained quantities of grass seeds.

Pheidole dentata var. *commutata* Mayr.

This variety differs from the typical *dentata* only in that the posterior half of the head, the dorsum of the pro- and mesothorax and that of the petiole and postpetiole are smooth and shining.

Distribution.—Cades Cove, 1800 ft.; Cove Mt., 2000 ft.; near Gatlinburg, 1500, 1600, 2000 ft.; Greenbrier Cove, 1800 ft.

This ant is rather common at low elevations in moist grassy areas partially shaded by trees. Like the typical *dentata* it nests beneath stones and has similar habits of nest construction. A number of colonies was found along the border of a grassy "opening" on Cove Mountain, and in the nest chambers seeds were extremely plentiful.

Pheidole morrisi Forel

The soldier of this species is dusky yellow to brown in color, and has the entire body hairy. The head is shining and the thorax, petiole, postpetiole and gaster are opaque. It may be distinguished readily from other members of the genus by its extremely short or tuberculate spines on the epinotum. The body length varies from 3.5 to 4 mm.

Distribution.—Greenbrier Cove, 1500, 1800, 2200 ft.; Greenbrier Cove (Talbot); near Gatlinburg, 1500, 2200 ft.; Davenport Gap, 2000 ft.; Cades Cove, 1800 ft.

P. morrisi is a common ant at low elevations where it inhabits dry grassy fields and slopes. All of the many colonies examined were very large and contained from hundreds to a couple of thousand workers and soldiers. Most of the nests were in the soil beneath large stones. When a stone was removed from a nest a great many large and variously shaped gallery openings were seen, together with numerous rather deep surface chambers. The vertical galleries extended into the soil for a depth of two to four feet and connected with many chambers of varied size and shape. Some colonies construct dome-shaped mounds of earth to a height of 12 cm. or more, and these are always perforated by many galleries and chambers. A few colonies observed had constructed mounds from which subterranean galleries led horizontally to beneath an adjoining flat stone. This stone, when removed, would present the same aspect as that of a nest without a mound. Males and alate females were in the nests during the middle of June. All castes are very active. The workers and soldiers move about with great speed when their nest is disturbed, and teem out of the galleries in enormous pugnacious hordes. The collector may shortly find himself almost covered with the workers especially, which bite

with alacrity, precision and viciousness. How different is their behavior from that of docile *vinelandica!*

Pheidole tysoni Forel

This is a rather uniformly rich yellow or orange colored ant. The shining head of the soldier is elongate and has nearly parallel sides. The body length is approximately the same as that of *vinelandica.*

Distribution.—Cove Mt., 2000 ft.; Greenbrier Cove, 1800 ft. (Talbot, Cole); near Gatlinburg, 1500 ft.

P. tysoni constructs nests in the soil beneath stones in dry grassy places. They are very similar to those of *vinelandica,* being of the same general pattern and depth, and are rather abundant in areas inhabited by *vinelandica.* The colonies consist of small numbers of sluggish workers and soldiers. I have found nests only beneath stones, but Dennis (1938, p. 282) reports a nest covering a square yard and not more than two inches deep. Presumably, this nest was without a stone covering. *P. tysoni* is far less common than *vinelandica* in the Park. Males and winged females were in the nests during late June and early July.

Pheidole crassicornis Emery

The antennal scapes, which are distinctly flattened at the base, clearly define the soldier of this species. The head, thorax, petiole and postpetiole are light to medium brown in color and the gaster dark brown or black. Erect hairs are abundant on the thorax, petiole, postpetiole and gaster, but very sparse on the head. The total body length is about 3.5-4 mm.

Distribution.—Gregory Mt., 1900 ft.; Cove Mt., 2000 ft.; Davenport Gap, 2000 ft.

A few nests of *crassicornis* were discovered in the Park. Each occupied a dry unshaded grassy area and was in the ground beneath a stone. At the base of Gregory Mountain was a number of colonies, but at higher elevations, such as that of Cove Mountain, the ants were very scarce. On Cove Mountain the two nests found were in a warm, bright, dry grassy area completely surrounded by second-growth pine. The nest architecture is much the same as that of *dentata* and its variety *commutata.*

Pheidole dentigula M. R. Smith

The soldier of this species is characterized chiefly by the two large coarse teeth on the gula. It is of a ferruginous color and has the head, thorax, petiole and postpetiole subopaque and the gaster shining. The body is about 2.5 mm. in length and is rather generally covered with hair.

Distribution.—Greenbrier Cove, 1800 ft.

A single small colony of what appears to be this species was found nesting in the ground beneath a stone on a grassy slope. The ants were in a small chamber at the base of a single vertical gallery extending about four inches into the soil.

Genus Crematogaster Lund

The ants of this genus usually live in large colonies beneath stones and logs, or under the bark of logs (and within the decayed heartwood) and standing dead trees. Some of them, however, occupy hollow stems and also nuts which have fallen to the ground. All are characterized superficially by the heart-shaped gaster, which, when the ant is moving, is carried partially bent over the back. Many of the species attend aphids and coccids on trees. The genus is well represented in the Park in numbers of colonies but not particularly well in numbers of species.

Key to the Species of Crematogaster in the Park

1. Epinotal spines short, not large; very small to moderately small ants..... 2
   Epinotal spines longer and larger; much larger and more robust ants..... 3
2. Epinotal spines robust and incurved; deep brown to blackish brown colored ants
   .....*ashmeadi* Mayr
   Epinotal spines not especially directed inward; pale yellow ants.....
   .....*minutissima missouriensis* Emery
3. Thorax coarsely sculptured, reticulate-rugose, the rugae usually with a distinct longitudinal trend, the interspaces punctate.....*lineolata* (Say)
   Thorax not as above; epinotal spines long, curved, acute; head and thorax brown, gaster black .....*laeviuscula* Mayr

Crematogaster ashmeadi Mayr

This ant has rather short, broad and sharp epinotal spines. It is of a chocolate brown color and about 2.5 mm. in body length.

Distribution.—Wears Cove road, 1700 ft.; Brushy Mt., 3200 ft.

A few colonies were found in rather open forests. They were most numerous in the Brushy Mountain oak-pine forest-type, where they were of medium size and nested in dry pine logs. Two other colonies were in an open woods bordering Little River in a valley, and they were nesting under the bark of logs.

Crematogaster minutissima missouriensis Emery

This ant may be recognized by the characters enumerated in the key.

Distribution.—Cades Cove, 2000 ft.

A single rather large colony of *missouriensis* was observed on a dry steep slope with an open stand of second-growth pine. The nest was in the soil beneath a stone. It extended into the soil to a depth of only about three inches, and consisted of two elongate interconnected chambers which opened by galleries to the entrance beneath the stone. Although there were but 47 workers found in the colony, supernumerary queens were present—56 of them. Both workers and queens were extremely sluggish in their movements.

Crematogaster lineolata (Say)

This common species, with reddish brown or dark brown head, thorax, petiole and postpetiole and dark brown or black gaster, is about 3 mm. in length.

Distribution.—Brushy Mt., 3000-4700 ft.; near Gatlinburg, 1500-2200 ft.;

Chimneys camp ground, 3300 ft.; Wears Cove road, 1700 ft.; Little River Gorge, 1565 ft.; Cove Mt., 2000 ft.; near Tremont, 1750 ft.; Greenbrier Cove, 1500-3000 ft.; Gregory Mt., 3000 ft.; Davenport Gap, 2000 ft.; Cades Cove, 1800 ft.; Cherokee Orchard, 1500 ft.; Greenbrier Pinnacle, 3000 ft.; near Elkmont, 2200 ft.; near Gatlinburg (Talbot); Greenbrier Cove (Talbot).

Nests of *C. lineolata* are abundant in the Park. Although they are most numerous in rather dry bright places at lower elevations, several colonies were observed at elevations as high as 4900 feet. In Greenbrier Cove and on the grassy slopes near Gatlinburg they are especially numerous. I found that they nested under stones as frequently as in wood and that the stones, which were very large and flat, were not at all imbedded in the soil but lay loosely upon it. Many large flat rocks, which I had removed and replaced loosely during the course of my studies of other ants, became inhabited beneath by colonies of *lineolata* after even comparatively short periods. The lower surface of such a rock would become so thickly covered with workers that it would appear black. Nests beneath stones extended only a very few inches into the soil or not at all. The brood was reared in depressions between the stone and the surface soil, and frequently along the grassy margin. Other colonies nested under loose bark of logs and standing dead trees and in decaying logs and stumps. In such places the wood, if decayed sufficiently, had galleries and chambers extending throughout.

The workers have a rather disagreeable odor. They move about slowly in loose files, and frequently carry the heart-shaped gaster curled over the thorax with the tip turned forward. At times they lie for long periods in large numbers with their legs somewhat outstretched and the venter appressed closely to the stone or wood. When disturbed by the collector they attack him sluggishly but pugnaciously, and retain a firm grasp on the victim with their mandibles. The colonies are usually of huge size. The workers seek honeydew and dead insects. In 1939, males were in the nests near Gatlinburg on June 10; males and winged females, June 17. At Greenbrier Cove both males and winged females were found in the nests on June 13, 1939; on Cove Mountain, September 15, 1938; and on Brushy Mountian pine heath, September 16, 1937. A mating flight was observed on Brushy Mountain heath bald, September 22, 1937.

Crematogaster laeviuscula Mayr

The characters in the key clearly define this species.

Distribution.—Chimneys camp ground, 3300 ft.; Ramsey Fork, Greenbrier Cove, 3000 ft.

This ant is much less common in the Park than is *lineolata*. Each of the two nests discovered was beneath the loose bark of a decaying log. The colonies were smaller than the average size of those of *lineolata*, and they were in rather moist shady places. The nests were rather superficial structures in that the galleries and chambers did not extend far into the logs. *C. laeviuscula* feeds in part upon the honeydew of aphids, but dead insects and other small animals constitute the bulk of its food.

Genus STENAMMA Westwood

These ants are small, possess vestigial eyes and have two keels on the clypeus. They live in small colonies beneath stones and dead leaves in rich shady woods.

Stenamma brevicorne diecki var. *impressum* Emery

The color of this ant is usually dark brown. The hind portion of the head and the thorax and nodes of the pedicel are slightly shining. The epinotal spines are very short, blunt and directed upwards, and the mesoepinotal impression is broad and deep. The average body length is about 3 mm.

Distribution.—Indian Gap, 5250 ft. (Kennedy, Talbot, Cole); Mt. Le Conte, 6000 ft.

This is the only member of the genus known from the Park. It was found only at high elevations. The ants live in small colonies of a few sluggish individuals beneath small stones and in rotting moss-covered logs in the wet densely shaded forests of spruce, fir or the two admixed. In the spruce-fir forest at Indian Gap colonies were rather numerous, and many of them inhabited the hollows in the undersurfaces of stones. Other colonies had one or two tiny chambers in the soil beneath small stones, while some nested just beneath the moss covering of logs. Brood was frequently found under the moss beside a stone or in the stone pockets. *S. impressum* is the most common ant at Indian Gap. Its habits are similar to those of *Myrmecina graminicola americana*. Males were collected in the nests at Indian Gap by Miss Talbot, September 2, 1939.

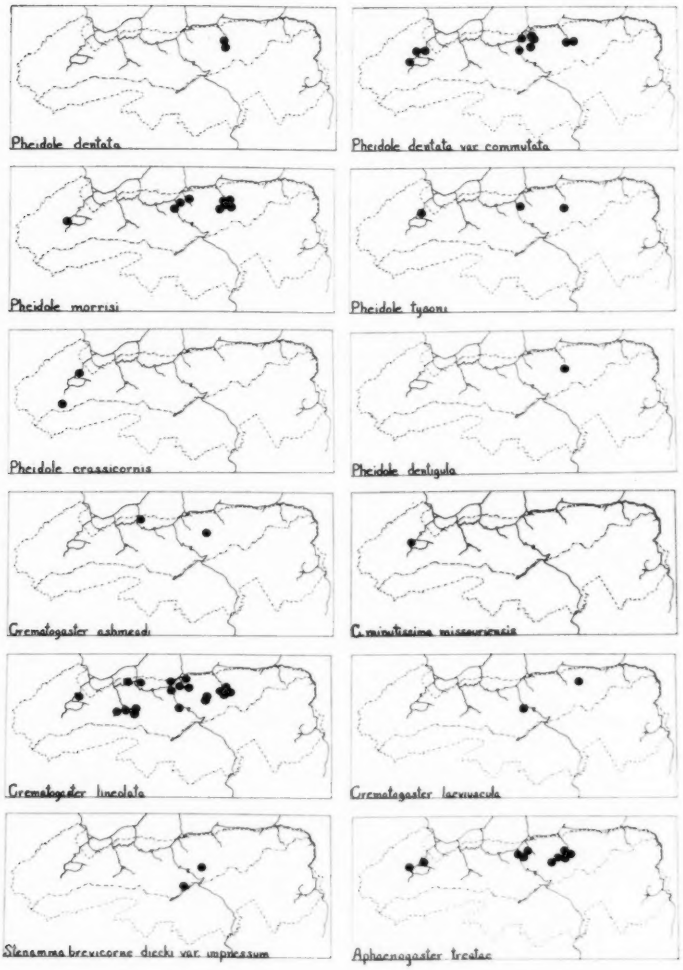
Genus APHAENOGASTER Mayr

The ants of this genus can be distinguished from those of *Myrmica* by the simple spurs on the tibiae of their hind legs. They move more rapidly than *Myrmica* and are, on the whole, far more numerous and their colonies more populous. They are inhabitants of moist places, and are abundant in wet decayed logs and beneath stones. Primarily, they are occupants of woods and forests, and are found from low elevations to those of about 5000 feet.

KEY TO THE SPECIES OF THE GENUS APHAENOGASTER IN THE PARK

1. Antennal scape with a prominent lobe at its base 2
   Not so 3
2. Antennal lobe considerably longer than broad, very much swollen or elevated near the base, when viewed in profile ..... *treatae* Forel
   Antennal lobe only slightly longer than broad, not elevated at its base ..... *treatae* var. *harnedi* Whlr.
3. Head with the posterior angles distinctly rounded 7
   Not so 4
4. Epinotal spines at least as long as the base of the epinotum; color red ..... *tennesseensis* (Mayr)
   Epinotal spines shorter than base of epinotum; color reddish brown or black 5
5. Epinotal spines somewhat longer than half the base of the epinotum ..... (typical) *fulva* Roger
   Epinotal spines shorter than half the base of the epinotum 6
6. Color reddish brown ..... *fulva aquia* (Buckley)
   Color pitchy black ..... *fulva aquia* var. *picea* (Emery)

PLATE 2


Pheidole dentata
Pheidole dentata var commutata
Pheidole morrisi
Pheidole tysoni
Pheidole crassicornis
Pheidole dentigula
Cremastogaster ashmeadi
C minutissima missouriensis
Cremastogaster lineolata
Cremastogaster lacviuscula
Stenamma brevicorne diecki var impressum
Aphaenogaster treatae

7. A prominent tooth-like plate or disc extending laterally from the frontal carina and covering part of the base of the antennal scape 8
   Not so 9
8. Color ferruginous red, appendages scarcely darkened.....*lamellidens* Mayr
   Of the same color, but the appendages much darkened.....
   .....*lamellidens* var. *nigripes* M. R. Smith
9. Head, and especially the thorax, very coarsely punctate; clypeus very rough and subopaque .....*texana punctithorax* Cole
   Not so 10
10. Epinotal spines short, directed upwards; color reddish brown, with the gaster dark brown except at the base .....*texana* var. *furvescens* Whlr.
    Epinotal spines directed more backward .....*texana* var. *carolinensis* Whlr.

Aphaenogaster treatae Forel

This is one of the largest species of *Aphaenogaster* known in the Park, its body length being about 6 mm. It is rather uniformly rich reddish brown in color. The head, thorax, petiole and postpetiole are subopaque and the gaster is shining.

Distribution.—Cades Cove, 1800 ft.; Cove Mt., 2000 ft.; near Gatlinburg, 1500-1800 ft.; Greenbrier Cove, 1800-3000 ft.; Brushy Mt., 3200 ft.

A. treatae is not an uncommon ant at some places in the Park. Invariably, it was found colonizing open woods (usually pine) or less frequently grassy fields and slopes. All nests were beneath stones of varying size, and each nest possessed a ingle entrance, either beneath or beside the stone, leading by a gallery to a series of large interconnected chambers deep in the soil. Beside or near the stone there was sometimes a scattering of earthen pellets which was made by the workers during nest enlargement. The colonies were populous and the workers very active. The association of this species with bright rather open areas is portrayed by the fact that in the cove hardwoods areas and in the rather dense stands of pine the colonies were found only in or at the edge of grassy areas and in open woods. In all cases, however, the soil was rather moist. The queen may be found easily by digging into the nest. Males were in the nests during middle and late September.

Aphaenogaster treatae var. *harnedi* Wheeler

The key characters indicate the important difference between this variety and the typical *treatae*. In color and size the two ants are about uniform.

Distribution.—Near Gatlinburg, 1500 ft.

A single colony of what is apparently this variety was found beneath a stone on a grassy slope. In habits this ant appears to be similar to the typical species. No earthen pellets were around the nest entrance.

Aphaenogaster tennesseensis (Mayr)

This is a rather uniformly rust colored ant with finely sculptured head, coarsely sculptured thorax and smooth petiole and postpetiole. The head and thorax are subopaque, the petiole more shining and the gaster very shining. The epinotal spines are very long, straight and rather slender. The body length is 4.5-5 mm.

Distribution.—Ramsey Fork, Greenbrier Cove, 3000 ft.; Chimneys camp ground, 3300 ft.

Three large colonies were located. Each of these nested in rotting but firm wood—two in stumps and the other in a hemlock log. In each case the nest openings were obscure. One nest in a stump extended down well within the roots, and the bulk of the colony, including much brood, seemed to be concentrated there. The females are very small in comparison with those of *treatae*, are smooth and possess huge epinotal spines. They probably establish their colonies in nests of *A. fulva* or its subspecies or varieties. *A. tennesseensis* is known only from regions where *fulva* and its closely related forms thrive. Several mixed colonies of the two forms, containing queens of *tennesseensis* only, are recorded in the literature. When in unmixed colonies, *tennesseensis* has been found always to nest in rotting wood.

Aphaenogaster fulva Roger

This species shows a great deal of variability in both structure and coloration, but the longer epinotal spines of the typical representatives will serve to distinguish *fulva* from its subspecies and variety.

Distribution.—Chimneys camp ground, 3300 ft.; Greenbrier Cove, 1700-2900 ft.; Gregory Mt., 3000 ft.; Cove Mt., 2000 ft.; Greenbrier Pinnacle, 3400 ft.; Brushy Mt., 3800 ft.

This species nests in logs, under them or their bark, and beneath stones in moist shady woods as well as in open woods. The colonies are of medium size. Logs inhabited by the ants are those which are rather well decayed and somewhat moist. The species is nowhere common, but it is well distributed among favorable habitats.

Aphaenogaster fulva aquia (Buckley)

The characters in the key will serve to distinguish this subspecies from the typical *fulva*.

Distribution.—Cove Mt., 2000 ft.; Brushy Mt., 3800, 4700 ft.; Greenbrier Cove, 1600-3000 ft.; Gregory Mt., 1500-2500 ft.; near Gatlinburg, 1600 ft.; Newfound Gap, 5250 ft.; Wears Cove road, 1700 ft.; Greenbrier Pinnacle, 3600 ft.; Cades Cove (Talbot, Cole).

A. fulva aquia is one of the most common ants in the Park. It inhabits shady moist woods, particularly those which are rather dense. The habitat tolerance seems not to be so broad as that of the typical *fulva*, since I failed to find this ant in very open woods or other drier and brighter places. Where it occurs it is remarkably abundant and nests in and under decaying logs and stumps and beneath stones. Usually the colonies are large and the nests expansive. Some logs were literally teeming with the ants. The logs were mined with horizontal galleries which connected with many large chambers, some of which were stored with bits of dead insects. Some of these nests contained subterranean galleries which connected with others leading to still another and adjoining log. Other galleries led to the surface beneath a nearby

stone. Nests which were found beneath stones frequently extended to a depth of three or more feet into the soil, and the galleries and chambers spread out so as to occupy a much greater area than that indicated by the stone covering the entrance. At higher elevations the ant was much less common, and at Newfound Gap only a few scattered colonies with small populations were found. The optimum elevation seems to lie between 1000 and 3000 feet.

Aphaenogaster fulva aquia var. *picea* (Emery)

This variety is always of a pitchy black color, and hence is easily separated from both the subspecies *aquia* and the typical species.

Distribution.—Alum Cave, 4700 ft.; 2 Mi. S. Cherokee Orchard; Alum Cave trail, 4100 ft.; Greenbrier Cove-Brushy Mt. trail, 1800-4700 ft.; Ramsey Fork, Greenbrier Cove, 1600-4000 ft.; Newfound Gap, 5045 ft.; Chimneys camp ground, 3300 ft.; Mt. Le Conte, 5600 ft.; Gregory Mt., 2000-2200 ft.; Cove Mt., 2000 ft.; Greenbrier Pinnacle, 3700 ft.; near Grassy Patch, 4000 ft.; trail to Chimney Tops, 4100 ft.; near Gatlinburg (Talbot).

Although this variety was found at elevations at low as 1600 feet, the number of colonies was decidedly few at this lower elevation. Also, the nests were not populous. The ant is very common at high elevations, particularly at those of more than 2500 feet. In such places it replaces *A. fulva aquia,* for the most part, not only in numbers of colonies but also, to a certain extent, in habitat. It is typically an ant of high elevations in the Park with the consequently favorable cool dense wet forests. In such places it colonizes moist well decayed logs or nests beneath stones. At all except the highest elevations, around 5000 feet, and the lowest ones, the colonies were populous and thriving. Some colonies nested in the ground beneath logs and had constructed galleries under the bark. At times the brood would be transported into the space between the bark and the wood where incubation by insolation was possible. In general, the habits of *picea* are similar to those of *aquia.* Winged males and females were found in nests during early and middle July.

Aphaenogaster lamellidens Mayr

This species is of a rusty red-brown color, with the appendages scarcely darkened. It is about 5 mm. in length.

Distribution.—Greenbrier Cove, 1800 ft.

A few colonies of *lamellidens* were found in wet rotting logs in a deeply shaded forest. The ant's habits are much like those of its variety *nigripes.*

Aphaenogaster lamellidens var. *nigripes* M. R. Smith

The variety *nigripes* can be distinguished readily from the typical *lamellidens* by its very dark, almost black, shining femora and tibiae, and by the much coarser sculpturing of the head, thorax, petiole and postpetiole. The antennal scapes of specimens found in the Park are black.

Distribution.—Chimneys camp ground, 3300 ft.; Greenbrier Cove, 1500-2100 ft.; Gregory Mt., 2600 ft.; Cove Mt., 2000 ft.

This ant is rather common at several places in the Park, and has been found always to nest in only slightly decayed logs or stumps in moist, rather heavily shaded woods. The ants construct large nests well within the log or stump, and frequently mine the entire internal structure with their galleries and chambers. The galleries generally run lengthwise in the matrix and between the sheets of annual growth, the interstices of which have become well decayed. The sluggish workers may be seen in the summertime ambling over the rocks at the edge of streams where they seek their food. Especially is this true immediately following a shower, which spreads an array of small insects on the boulders. All but two nests were found in cove hardwoods; these two occupied stumps in a dense moist area of second-growth pine.

Aphaenogaster texana punctithorax Cole

This ant, whose body length is about 3.8 mm., is of a grayish black color with the legs and antennae dusky yellow and the antennal scapes somewhat infuscated.

Distribution.—Gregory Mt., 2400 ft. *(type locality)*

A single very small colony of this ant was discovered beneath a stone on a wet slope of deciduous forest. There is a distinct possibility that these ants represent only minima of another species of *Aphaenogaster*, perhaps *fulva aquia* var. *picea*.

Aphaenogaster texana var. *furvescens* Wheeler

The characters incorporated in the key will serve readily to distinguish this ant from others.

Distribution.—Cades Cove, 1800 ft.

Two nests of this variety were discovered in the ground beneath stones in a moist shaded area of old-field pine. The colonies were rather small and occupied a series of horizontal chambers close to the soil surface. Two or three small circular entrances were under a stone.

Aphaenogaster texana var. *carolinensis* Wheeler

This variety is reddish brown in color, with the gaster brown and its base and tip paler. The antennae are ferruginous and the legs yellow.

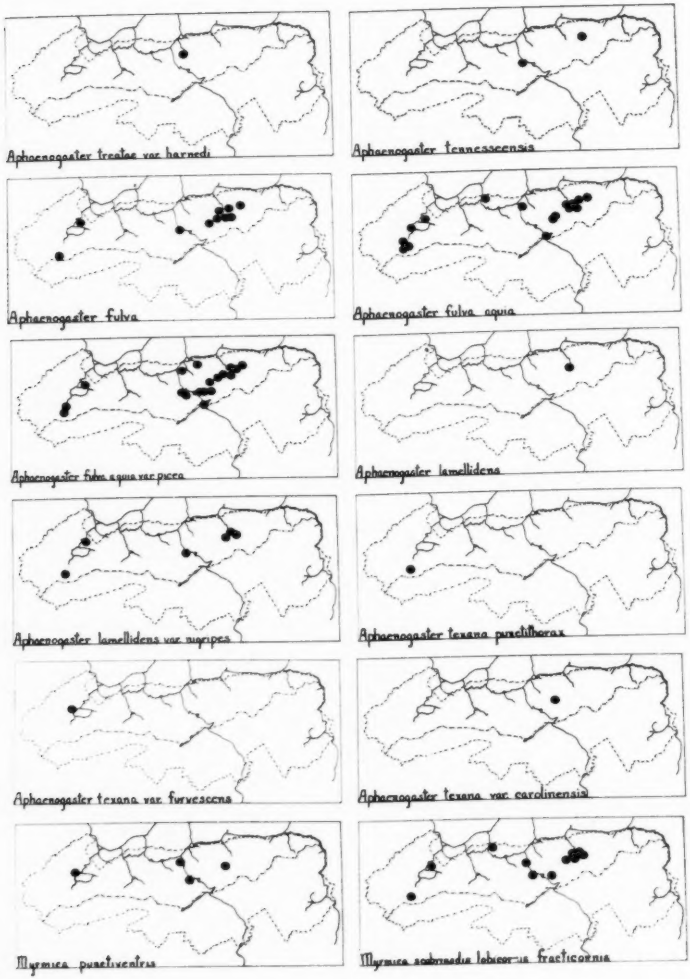
Distribution.—BrushyMt., 3200 ft.

A very few small colonies of *carolinensis* were found in nests beneath stones in an area of oak-pine. Each nest was similar in pattern to that of the variety *furvescens*. Workers were observed ambling over the dry ground in the brighter parts of the area apparently seeking food.

Genus MYRMICA (Latreille) Mayr

Ants of the genus *Myrmica* are easily distinguishable from those of the genus *Aphaenogaster*, with which they may be confused, by the pectinate tibial spurs of their hind legs. They are sluggish individuals which live under stones in rather moist places, such as in wet woods or along streams. Their

PLATE 3


Aphaenogaster treatae var. harnedi
Aphaenogaster tennesseensis
Aphaenogaster fulva
Aphaenogaster fulva aquia
Aphaenogaster fulva aquia var. picea
Aphaenogaster lamellidens
Aphaenogaster lamellidens var. nigripes
Aphaenogaster texana parvithorax
Aphaenogaster texana var. fumescens
Aphaenogaster texana var. carolinensis
Myrmica punctiventris
Myrmica scabrinodis lobicornis fracticornis

specific diagnosis is difficult without the male caste. Only two members of the genus have been found in the Park.

KEY TO THE SPECIES OF MYRMICA IN THE PARK

Epinotal spines longer than the epinotal declivity.....*punctiventris* Roger
Epinotal spines shorter or no longer than the epinotal declivity.....
.....*scabrinodis lobicornis* var. *fracticornis* Emery

Myrmica punctiventris Roger

This is a small species (3-3.5 mm. in length) with dark brown head and gaster and paler thorax and appendages. The head, thorax and pedicel are very coarsely sculptured.

Distribution.—Cades Cove (Talbot); near Gatlinburg (Talbot, Cole); Greenbrier Cove, 2600 ft.; Chimneys camp ground, 3300 ft.

M. punctiventris appears to be not at all common in the Park. A single colony was discovered in Greenbrier Cove, but only stray workers were collected at the other points listed. The ants nest in small colonies beneath stones in shady woods.

Myrmica scabrinoidis lobicornis var. *fracticornis* Emery

This variety has a rather coarsely sculptured head, thorax, petiole and postpetiole, and a very smooth shining gaster. The body is rather uniformly covered with hairs. The head and dorsal surface of the first segment of the gaster are dark reddish brown, with the thorax, petiole, postpetiole and appendages and the remainder of the gaster lighter.

Distribution.—Greenbrier Cove, 1800, 2600 ft.; Alum Cave, 4700 ft.; Chimneys camp ground, 3300 ft.; Cove Mt., 2000 ft.; Wears Cove road, 1700 ft.; Gregory Mt., 2600 ft.; near Gatlinburg, 2000 ft.

Colonies of *fracticornis* are not common in the Park, but at some places they are well represented. They were most numerous along the streams at lower elevations, while at higher elevations they were found beneath stones in moist shady forests. In Greenbrier Cove, along Porters Creek, and at the Chimneys camp ground, bordering Roaring Forks, several nests were discovered under moss on stones at the water's edge. These nests usually extended into the soil beneath the stones in spite of the stones' being tightly imbedded in the earth. The small nest chambers were at shallow depths of the soil or beneath moss. The workers are slow of movement and were seen often ambling about on the surfaces of rocks and boulders on the stream margins. At all other localities indicated the ants nested in the ground beneath stones and constructed a few chambers near the soil surface.

Genus LEPTOTHORAX Mayr

Among our more interesting ants are these diminutive species of the genus *Leptothorax*, since they have such a diversity of habits. Yet they are perhaps the least conspicuous members of the Formicidae. All the species live in small colonies, sometimes with not more than 25 to 50 individuals, in small cavities in the soil, between stones or in the hollow stems of plants. Galls on plants

provide many excellent nesting sites, and even hollow nuts may be colonized by the genus.

None of our species is particularly common in the Park. Furthermore, those which are present are rather difficult to find owing to the diminutive size of the individuals and the small colonies in which they live. One may frequently find stray workers ambling about in search of food, and the nests of these may be most easily located if one has the patience to follow a worker to its nest—a matter of several hours' time, in most cases. The tiny entrance to the nest is usually such that only an entering worker will reveal it to the collector.

Occasionally, *Leptothorax* lives as guests in nests of other and larger ants. A single species, *L. tennesseensis*, is the only one known to attend aphids, and this is a rare members of the ant fauna of the Park. Most species are timid and also lack the agility of a great many of our ants, feigning death when disturbed. So far as known from the Park there are five species represented. Their range in the region shows adaptability to differences of moisture, temperature, soil and vegetation. For example, *L. curvispinosus* inhabits moist shady woods, while *L. pergandei* occurs in rather dry soil with sparse vegetation.

The antenna of the worker bears usually a distinct 3-jointed club. The thorax is slender and does not possess a promesonotal suture (except in *tennesseensis*). The epinotum bears a pair of teeth or spines. The petiole has a median ventral tooth but the postpetiole is unarmed ventrally. The gaster is broadly elliptical, compressed dorsoventrally and its basal three-fourths is formed by the first segment. The spurs of the middle and hind legs are not pectinate. The species are yellow, brown, or black, and most of them have the head, thorax and pedicel sculptured and opaque. The gaster is always very smooth and shining.

KEY TO THE SPECIES OF LEPTOTHORAX IN THE PARK

1. Antennae 11-jointed 2
   Antenna 12-jointed 4
2. Epinotal spines very short, tooth-like; color deep brown or black ..... *fortinodis* Mayr
   Epinotal spines long 3
3. Epinotal spines very long, stout, horizontal, their tips curved slightly inward and downward; body dark colored ..... *longispinosus* Roger
   Epinotal spines slender, their tips curved slightly inward and upward; color yellow, sometimes infuscated ..... *curvispinosus* Mayr
4. Promesonotal impression present; thorax rich light tan, gaster darker ..... *tennesseensis* Cole
   Promesonotal impression wanting; body black or dark brown ..... *pergandei* Emery

Leptothorax fortinodis Mayr

The head, thorax and pedicel are deep reddish brown, while the gaster is black. The mandibles, antennae and legs are red, and the antennal club and often also the femora are tinged with black. The head is mostly opaque, and the thorax, petiole and postpetiole are subopaque. The gaster is smooth and shining. The body has a total length of 2.5-3 mm.

Distribution.—Chimney Tops, 4756 ft.; Chimneys camp ground, 3300 ft.;

Little River Gorge, 1565 ft.; Greenbrier Cove, 2900 ft.; Brushy Mt., 3800, 4900 ft.; Alum Cave, 5000 ft.

This little ant was found in a few places in the Park nesting in dead twigs or under the dry crusty peat layer of the heath balds. It was nowhere common and was never observed nesting beneath stones. It makes tiny, rather superficial nests and lives in small colonies, usually of a hundred or fewer workers. The ant occupies rather open habitats. On the Brushy Mountain heath bald males and winged females were taken from a nest on August 5, 1939.

Leptothorax longispinosus Roger

The head and gaster of this ant are black, the thorax and pedicel dark brown and the legs yellow. The scape, club, coxae and femora are tinged with black. The head is shining, the gaster very smooth and shining and the thorax, petiole and postpetiole opaque, except for the somewhat shining mesonotum. The body length is 2.25-2.5 mm.

Distribution.—Greenbrier-Brushy Mt. trail, 2800, 2900, 4000 ft.; Gregory Mt., 3300 ft.; Cove Mt., 2000 ft.; Brushy Mt., 4900 ft.

The ants of this species are far more numerous than those of *fortinodis*, and they nest in rather dense moist forests where they live beneath stones, in decayed nuts or, more rarely, within rotting logs. Many workers were observed crawling about on the leaves of Solomon's seal in the damp shady areas of the cove hardwoods. The colonies varied considerably in strength, but most of them were small. The subterranean nests were very shallow, and each consisted of only a single small chamber with a tiny circular gallery leading to the surface. In one instance I discovered an entire colony occupying a nest one-half inch deep beneath a pebble about one-quarter of an inch in diameter.

Leptothorax curvispinosus Mayr

This small yellow species has the head, thorax, gaster and sometimes the femora lightly tinged with brown. The edges of the mandibles and a large triangular spot on either side of the first gastric segment are dark brown or black. The head and thorax are opaque and the gaster and legs smooth and shining.

Distribution.—Brushy Mt., 3800 ft.; Cove Mt., 2000 ft.; near Gatlinburg (Talbot).

I collected *curvispinosus* from only two places in the Park, and yet at both places it was common. The habitat in each case was pine woods. The nests were in hollow stems and twigs of herbs and shrubs, and one nest was found in the ground at the base of a clump of grass. During late spring and early summer the workers were abundant on plants where they foraged for honeydew and dead insects. Some of the colonies were comparatively large, containing as many as 150 or more workers. This species appears to be not so common in the Park as is *longispinosus*.

Leptothorax tennesseensis Cole

This ant is of a rich light tan color, and the antennae, dorsal surface of

the head, petiole and postpetiole are much darker. The apex of the antennal club is yellow. The hairs are long, slender and very abundant.

Distribution.—Greenbrier Cove, 2000 ft. *(type locality).*

Only a few workers of this species were collected. They were attending aphids on stems of golden ragwort in an area of broomsedge grass.

Leptothorax pergandei Emery

This species is of a rich dark brown or black color, with the frontal carinae, antennae (except the club), thorax, pedicel and legs yellowish red or brownish yellow. In some specimens the dorsal surface of the thorax is blackened, while in others the entire thorax and the legs are black, except the petiolar peduncle and the tarsi, which are yellow. Hairs are long and abundant. The body length is 2.5-3.25 mm.

Distribution.—Brushy Mt., 3200 ft.; near Gatlinburg (Talbot).

One small colony of this ant was found in the Park. It occupied a small subterranean nest without a protected entrance in a bright warm area of pine heath. Less than 25 workers comprised the colony. I found the nest after I had observed and followed a worker moving rather agilely over the soil.

Genus STRUMIGENYS F. Smith

This genus includes some of our smallest ants, all of them being less than 3 mm. in body length. Their color is obscure, and because of this, together with their sluggish behavior and their death-feigning habit, they are easily overlooked by collectors. The ants may be readily distinguished from those of other genera by their 6-jointed antennae and cordiform heads. They live in small colonies—usually of less than 100 workers—within decaying logs and stumps. Some nests have been found in soil beneath surface covers, such as stones and bark. Decaying pine logs seem to be particularly favorable abodes, and the small colonies may be found occupying minute galleries in the moist rotted matrix. Some species of *Strumigenys* are at least partially predacious on Collembola. Colonies are frequently in the vicinity of nests of other kinds of ants.

Strumigenys creightoni M. R. Smith

This species, the only one of its genus known from the Park, is ferruginous in color and has the mandibles, antennae and legs lighter. It varies in body length from 1.9 to 2.1 mm. The head bears a number of spatulate hairs, and the border of the clypeus has 14 to 16 anteriorly directed scale-like hairs.

Distribution.—Cades Cove (Talbot).

In spite of extensive collecting in the Park, I have been unable to locate a colony of *Strumigenys,* although I have been aware that the genus must be represented. I was delighted, therefore, when I learned that Miss Talbot had found colonies of *creightoni* in an oak-pine area during her short collecting sojourn in the Park. According to her field notes, the colonies were in a "pine log so thoroughly sunk into pine needles and soil that it is just a ridge covered with pine needles and extensive patches of *Lucobryum* moss." At the top of

the log, under a thick covering of moss, at a depth of one inch in the red decayed wood was the main gallery of one nest. It was about two inches in length and less than one-quarter of an inch broad, and contained larvae and pupae. There were other narrower galleries. The end of the main gallery was white with fungus hyphae, and a number of the ants was there. From this nest Miss Talbot took 123 workers, 6 dealate females, and 17 alate females (September 1, 1939), and apparently these comprised the whole colony. From another nest she collected 75 workers, 4 dealate females, and 2 alate females; and from the third colony, 79 workers, 1 dealate female, and 1 male.

Genus TRACHYMYRMEX Forel

Trachymyrmex is represented in the Park by one variety, which, like its relatives, is a fungus-growing ant.

Trachymyrmex septentrionalis obscurior var. *seminole* Wheeler

This spiny little ant is easily distinguished from all other ants of the Park. Besides the rough integument with spines and tubercles, the surface is covered with gray granules or glistening particles and the gaster is somewhat globose in shape. The color of the body is brownish yellow, the frons and vertex of the head are dark brown or black and there is a dark brown spot in the dorsal impression of the postpetiole and a median dorsal stripe of the same color on the first segment of the gaster.

Distribution.—Wears Cove road, 1700 ft.

Nesting only in sandy soil, this ant colonized a grassy, sandy open area in a valley of the Park. Each nest was usually marked by a crescentic or circular mound of sand about seven inches in diameter. Near the center was the single circular entrance leading perpendicularly into one or a series of subterranean chambers placed generally one below another. In at least one of the hard smooth-walled chambers rather deep in the soil the ants cultivated a fungus whose hyphae produce bodies upon which the ants feed. Transferred from the parental nest to the infrabuccal pocket of the female, a tiny pellet of the fungus is expelled by the queen into a chamber of her new nest. The pellet is fertilized by the queen's fecal matter, and the fungus gradually grows and expands until it assumes the form of a spongy mass which may all but fill the chamber. The eggs are laid, and the brood deposited, in the interstices of the fungus bed. The colonies in the Park are small. The workers are timid and move with such slowness and deliberation that collecting them is simple.

Subfamily DOLICHODERINAE

KEY TO THE GENERA OF THE SUBFAMILY DOLICHODERINAE IN THE PARK

1. Integument hard and brittle; declivity of epinotum strongly concave ..... *Dolichoderus* Lund
   Integument thin and flexible; declivity of epinotum not strongly concave 2
2. Petiolar scale vestigial or absent ..... *Tapinoma* Förster
   Petiolar scale well developed 3
3. Epinotum with a conical elevation ..... *Dorymyrmex* Mayr
   Epinotum without a conical elevation ..... *Iridomyrmex* Mayr

Genus Dolichoderus Lund

This interesting genus is distinguished from other genera of Dolichoderinae by the strongly concave declivity of the epinotum and by the integument's being hard and brittle instead of thin and flexible. The colonies are extremely populous, being composed usually of thousands of individuals, and nest in very dry, especially sandy, soil. The nests are frequently constructed around the roots of grass, and nothing but the files of workers may mark the entrance. The workers attend aphids and mealybugs on herbs, shrubs and trees, and are rather sluggish in their movements when undisturbed.

Key to the Species of Dolichoderus in the Park

1. Body distinctly hairy above; base of gaster with reddish yellow spots....*plagiatus* Mayr
   Body hairless or almost hairless above, especially the thorax and petiole..... 2
2. Head, thorax and petiole red, gaster black with yellowish spots.....*mariae* Forel
   Body and appendages deep black .....*taschenbergi* var. *atterima* Wheeler

Dolichoderus plagiatus Mayr

The head is black, the thorax, legs and antennal scapes reddish brown, the funiculi dark brown and the gaster dark brown with a dull yellow base. The head and thorax are subopaque, and the petiolar scale and gaster are shining. Hairs are rather numerous on the head and thorax, but are very sparse on the dorsal surface of the gaster. The body length is about 3.5 mm.

Distribution.—Brushy Mt., 3200 ft.

A number of small colonies of *plagiatus* was discovered in an area of oak-pine. The nests were in the soil, and consisted of a few small basal chambers leading by connecting galleries to single unprotected surface openings. The workers were moving about on the soil and on herbs.

Dolichoderus mariae Forel

This gorgeous red and black ant may be recognized easily by the characters used in the key. It has a body length of about 4 mm.

Distribution.—Cove Mt., 1900 ft.

Two huge colonies of this species were found in a grassy "opening" of a forest of second-growth pine. They were nesting in the ground at the base of clumps of dry grass. A single large gallery led to the nest chambers at a depth of about two feet in the soil. Workers were ambling about over the grass and attending aphids on nearby shrubs.

Dolichoderus taschenbergi var. *atterima Wheeler*

This is a beautiful shining jet black ant with a body length of about 4 mm.

Distribution.—Cove Mt., 2000 ft.

One large colony of this ant, comprising thousands of workers, was found in a grassy area within a forest of second-growth pine. The nest was much the same in construction as that of *mariae*, but was at the base of a large mass of dry grass between two stones. The main chambers were in the soil to a depth of about 30 inches and connected by galleries to the single nest entrance; but

there were several shallow chambers and horizontal galleries beneath the two stones, and brood was found in some of these.

Genus Dorymyrmex Mayr

This genus, which is distinctly of southern origin, is represented in the Park by the single species *pyramicus* and its variety *flavus*. Both of these ants are inhabitants of dry sandy soil in open situations where they construct symmetrical crater mounds of sand. They are very active, and when a nest is disturbed they teem out in great numbers to attack the intruder. *Dorymyrmex* is very easily distinguished from all other ant genera by the conical elevation on the epinotum.

Key to the Species of Dorymyrmex in the Park

Body light brown or dark brown .....*pyramicus* (Roger)
Head, thorax and gaster yellow, the latter more or less infuscated .....
.....*pyramicus* var. *flavus* McCook

Fig. 16. Crater mound of *Dorymyrmex pyramicus*. Photo by A. C. Cole.

Dorymyrmex pyramicus (Roger)

This small ant has a body length of about 3.5 mm. It varies considerably in the shade of brown, but the gaster is generally darker than the head and thorax. In most specimens the thorax is reddish brown.

Distribution.—Wears Cove road, 1700 ft.

D. pyramicus was found in only one area in the Park. Six colonies were

closely aggregated in a very sandy abandoned field. The vegetation was scant, and consisted of grasses and other low herbs. The soil was very warm and dry. Each nest had a completely exposed circular crater of sand about 4½ inches in diameter and ¾ inches in height in the center of which was a single very circular entrance about one-eighth of an inch in diameter. Each colony was populous, and brood was stored in a chamber about 6 inches from the nest entrance, at the end of a single gallery extending diagonally into the soil. The worker of *pyramicus* and that of its variety *flavus* are two of the most active ants in the Park, and vie with the two forms of *Iridomyrmex* and perhaps *Pheidole morrisi* in this respect. The ants mill out of the nest entrance at the least disturbance and climb continually up and down stems of nearby grass and weeds.

The area in which *pyramicus* was found is of great interest. The habitat is a very distinct one. Being in a valley, unshaded, level and with a loose, well-drained, extremely sandy soil, it presents an insect fauna which is essentially southern in its affinities. Associated with *pyramicus* was its variety *flavus*, together with *Trachymyrmex septentrionalis obscurior* var. *seminole* and *Iridomyrmex pruinosus* and its variety *analis*, all of which are rather distinctly southern elements. Many mutillids and bembecids had colonized the area. This place may be located readily by turning off the Maryville to Gatlinburg highway at the road to Line Springs. There is a sign at this intersection bearing the inscription "Wears Cove." The area lies on either side of the gravel road between the highway and the stream.

Dorymyrmex pyramicus var. *flavus* McCook

This variety differs from the typical species by its yellow head, thorax and gaster. The gaster of most workers in the Park has a rather distinct smoky tinge.

Distribution.—Wears Cove road, 1700 ft.

In the same area as that described for *pyramicus* were hundreds of crater nests of *flavus*. I counted 86 of their craters, varying from 2 to 4 inches in diameter, in a plot 25 feet square. This is by far the most common ant of that location, but it has not been collected elsewhere in the Park. The nests were scattered widely, and yet none of them was found very near the cluster of *pyramicus* craters. Each possessed a crater mound of sand of approximately the same dimensions as those of a mound of *pyramicus*, with a single, central, circular or oval entrance about one-quarter of an inch in diameter. In other respects, the nest construction was like that of *pyramicus*.

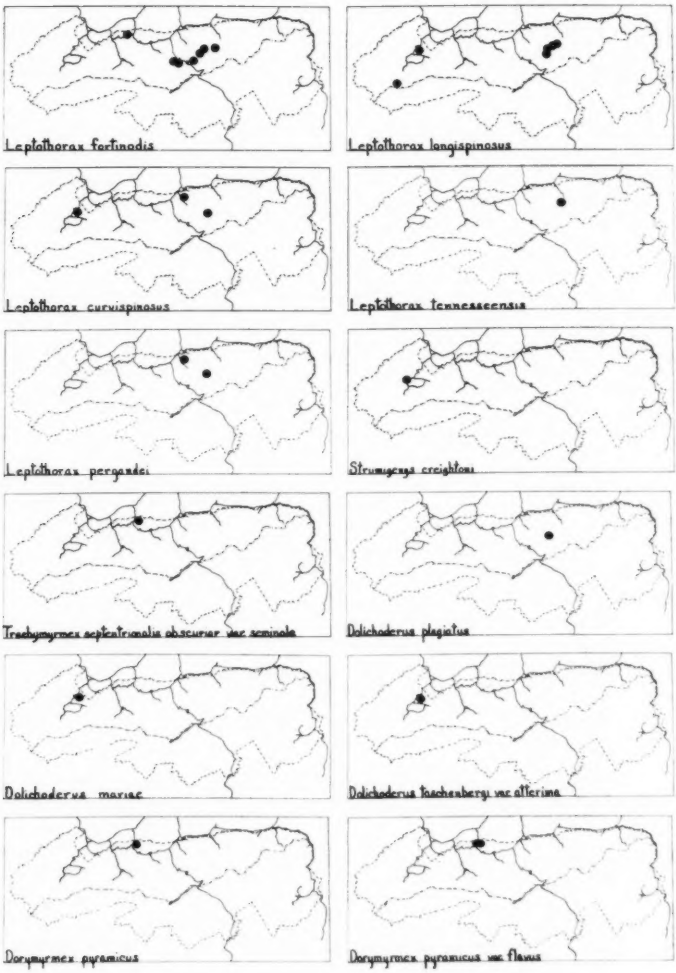
Genus TAPINOMA Förster

This genus has the scale of the petiole vestigial or absent, and on the basis of this character it can be separated readily from other genera of Dolichoderinae. The only species known in the Park is *T. sessile*.

Tapinoma sessile (Say)

This common species has a body length of 2.39 to 3.19 mm. It has a deep brown to black body color, with lighter mandibles and appendages. The

PLATE 4


Leptothorax fortinodis
Leptothorax longispinosus
Leptothorax curvispinosus
Leptothorax tennesseensis
Leptothorax pergandei
Strumigenys creightoni
Trachymyrmex septentrionalis obscurior var seminole
Dolichoderus plagiatus
Dolichoderus mariae
Dolichoderus taschenbergi var alterina
Dorymyrmex pyramicus
Dorymyrmex pyramicus var flavus

surface is subopaque and slightly glossy, and the mandibles and the anterior border of the head are more shining. The sparse hairs are confined to the mandibles, clypeus, prosternum, coxae, the ventral surface of the gaster and the dorsal surface of the fourth gastric segment.

Distribution.—Brushy Mt., 3800, 4900 ft.; near Gatlinburg, 1500-1800 ft.; Wears Cove road, 1700 ft.; Cove Mt., 2000 ft.; Greenbrier Cove, 1500, 1800, 2600, 4000 ft.; Alum Cave, 5000 ft.; near Grassy Patch, 3800 ft.; Davenport Gap, 2000 ft.; Cades Cove, 1800 ft.; near Tremont, 1700 ft.; Cherokee Orchard, 1600 ft.; near Gatlinburg (Talbot).

T. sessile was collected in the Park at many places to an elevation of almost 5000 feet. It was confined for the most part to rather open situations, although nests have been observed in dense moist woods. The ants nest in the soil beneath stones, logs, stumps and strips of bark. The nests are shallow affairs extending no more than an inch or two beneath the soil surface. Most of those in the Park were under rather large flat stones loosely appressed to the soil. Beneath such a cover the orange colored brood was confined to pockets in the soil, or to superficial chambers made by the workers, or very frequently scattered alone one inner margin of the stone and mingled with detritus. The colonies were generally populous. The pugnacious workers are always somewhat swift of movement and swarm over the intruder. When one of the ants is crushed by the fingers, an odor like that of rancid butter will be emitted. This is a characteristic of all of the ants of the subfamily Dolichoderinae, but it is especially pronounced in *Tapinoma*. The winged males were found in nests on grassy slopes near Gatlinburg as early as June 10, 1939, and the alate females, June 28.

Genus Iridomyrmex Mayr

The genus is represented in the Park by two forms. One of these, *I. pruinosus*, is rather uncommon, and its variety *analis* is scarce. These ants live in the soil beneath stones or have their nests marked by small earthen mounds. They invariably colonize the drier areas, and are particularly well represented in the most dry, sunny, open places, such as sandy meadows and abandoned land. The workers are extremely active, and it is usually very difficult to pick them up with forceps without injuring them. As a rule the colonies are populous and form aggregations.

Key to the Species of Iridomyrmex in the Park

Body of a rather uniform brown color ..... *pruinosus* (Roger)
Head and thorax brown; gaster much lighter in color, usually yellow ..... *pruinosus* var. *analis* André

Iridomyrmex pruinosus (Roger)

This is a dark reddish brown species with the body smooth and the head and gaster covered with a fine silvery pubescence, so that these regions appear subopaque. The hairs are very sparse. The body is about 3 mm. in length.

Distribution.—Greenbrier Cove, 1800 ft.; Wears Cove road, 1700 ft.; Cades Cove, 1800 ft.; near Tremont, 1700 ft.; near Gatlinburg, 2000 ft.

Nests of this species are apparently uncommon in the Park, in spite of their fairly wide distribution, and they are inhabitants of low elevation. Invariably they were found in open grassy fields in the soil beneath stones. The colonies were all rather small.

Iridomyrmex pruinosus var. *analis* Er. André

This variety differs from the typical species in that the body is distinctly bicolored, the head and thorax being dark brown and the gaster dusky yellow.

Distribution.—Cades Cove, 1800 ft.; Wears Cove road, 1700 ft.

This ant was found in only two places in the Park, and yet at each one of these the colonies were somewhat numerous. Each location was an old grassy field with dry sandy soil and an open stand of grass and weeds. All colonies were in the ground beneath stones, and the nest chambers extended to depths of 8 to 12 inches. The workers are extremely active, and run about over the hot soil at a remarkable speed. Like the typical *pyramicus*, this variety was found only at lower elevations.

Subfamily Formicinae

Key to the Genera of Formicinae in the Park

1. Antennae 9-jointed ..... *Brachymyrmex* Mayr
   Antennae with more than 9 joints 2
2. Workers polymorphic ..... *Camponotus* Mayr
   Workers not polymorphic, but often of variable size 3
3. Clypeal fossa distinctly separated from antennal fossa ..... *Prenolepis* Mayr
   Clypeal fossa confluent with antennal fossa 4
4. Joints 2-5 of funiculus shorter or not longer than succeeding joints; ocelli usually absent ..... *Lasius* (Fabricius) Mayr
   Joints 2-5 of funiculus longer than succeeding joints; ocelli distitnct ..... *Formica* (Linne) Mayr

Genus Brachymyrmex Mayr

Of this small genus the only species known from the Park is *B. heeri depilis*. This ant constructs nests of varying size beneath stones in rather dry open places, and in the Park has been taken only on the heath balds and in a pine-heath area. It may be distinguished easily from all other genera of the Formicinae by its 9-jointed antennae.

Brachymyrmex heeri depilis Emery

This tiny ant (1.5 mm. in body length) is of a dirty yellow color with pale yellow appendages. The body is subopaque and is very hairy, the hairs being present chiefly on the clypeus and the posterior half of the dorsum of the gaster.

Distribution.—Chimney Tops, 4756 ft.; Brushy Mt., 3800, 4900 ft.; Alum Cave, 4700 ft.

In the Park this ant is characteristic of the heath balds, where it and *Lasius brevicornis* are dominant species. Like its habitat associate, *depilis* lives in the soil beneath stones and decayed roots and stems lying on the dry

peaty surface. It attends root aphids in its nests whose subterranean chambers have been found frequently to extend to a depth of two or even more feet. The chambers are constructed around roots of heath plants on which the aphids feed, and are connected by a series of undulating galleries. A few nests were found in the Brushy Mountain pine heath. Males and alate females were in the nests during September.

Genus Prenolepis Mayr

Members of this genus, which is well represented in the Park only by *P. parvula,* are distinguishable from other Formicinae with which they might be confused by the clypeal fossae being distinctly separated from the antennal fossae. The genus is divisible into two subgenera, which are indicated in the key below. Many of the species feed upon the honeydew of aphids and coccids and upon nectar and other plant juices. Colonies live in the ground with or without a small mound near the entrance, or beneath stones, logs or stumps.

Key to the Species of Prenolepis in the Park

1. Mesonotum strongly constricted and cylindrical. (*Prenolepis* Mayr, s. str.) 2
   Mesonotum strongly constricted but never cylindrical. (Subgenus *Nylanderia* Emery). Antennal scapes without suberect or erect hairs.....*parvula* Nylander
2. Length of body 3-4 mm. 3
   Length of body 2-2.5 mm.; color reddish yellow, gaster paler and only slightly infuscated across the middle of each segment, legs and antennae pale yellow.....*imparis* var. *pumila* Wheeler
3. Body piceous black in color; mandibles, antennae, tibiae and tarsi lighter.....*imparis* (Say)
   Body brownish or reddish yellow, gaster and occipital region darker, legs yellow .....*imparis* var. *testacea* Emery

Prenolepis (Nylanderia) parvula Mayr

This shining little brown ant has a body length of about 2 mm., and can be recognized easily by the abundant long, thick, dark brown hairs. The appendages are lighter in color than is the rest of the body.

Distribution.—Brushy Mt., 3300, 3800, 4700 ft.; near Gatlinburg (Talbot), 1500 ft. (Cole); Cove Mt., 2000 ft.; Greenbrier Cove, 1500-3000 ft.; Cades Cove. 1800 ft.; Cherokee Orchard, 1600 ft.; Davenport Gap, 2000 ft.; near Tremont, 1700 ft.; Gregory Mt., 3000 ft.

This is one of the most common ants in the Park. It abounds at lower elevations in grassy areas—fields, slopes, "islands"—and in open woods. Wherever the soil is rather dry and warm, the sunshine bright and the elevation comparatively low, stones and wood cover nests of this active little ant. Most of the colonies contained a large number of individuals. In open woods nests were found in logs and stumps; and in grassy spots where stones were scarce the little crater mounds were abundant. The nests in the soil beneath stones are shallow constructions consisting of several superficial surface chambers and a few small basal ones at a depth of about 3 inches. In dense woods only a few nests were observed, and these were in old logs and stumps. Most colonies contained numbers of males and alate females in early spring, particularly in late March and during April.

Prenolepis imparis (Say)

This is a very smooth and shining species varying in color from pale castaneous to dark piceous brown, with the thorax and anterior part of the head generally paler and the gaster darker and more blackish. It and its varieties have the gaster broad basally and tapering to a rather pronounced point apically. The length of the body is 3-4 mm.

Distribution.—Chimneys camp ground, 3300 ft.; Brushy Mt., 3200 ft.; Gregory Mt., 1500 ft.; near Tremont, 1700 ft.

This species is not common in the Park. Several nests were discovered in the Brushy Mountain oak-pine area and a few colonies were observed elsewhere. The ants nest in shaded, moist, compact soil, particularly clay, occasionally beneath wood or stones; but more usually construct obscure crater mounds consisting of pellets of soil scattered around the single nest entrance. The workers are slow of movement; but are most active in the shade or on cool cloudy days. *P. imparis* is known as one of the "honey ants." Certain workers are called repletes since the gaster is greatly distended by "honey" in the crop. This "honey" is obtained chiefly from the sweet exudations of aphids and coccids which the ants attend outside their nests, and is stored in the repletes and utilized as food by members of the colony. Nests in the Park were rather superficial in extent, and consisted of a small series of chambers extending to a depth of but a few inches into the soil. Males and alate females were in nests on Brushy Mountain, September 22, 1937.

Prenolepis imparis var. *pumila* Wheeler

This variety is of the same pale color as that of the variety *testacea*, but it is noticeably smaller (2.2-2.6 mm.). The gaster is somewhat lighter in color than that of *testacea*, and is only lightly touched with black across the middle of each segment. The legs and antennae are pale yellow.

Distribution.—Cove Mt., 2000 ft.

Only one collection of this ant was made in the Park. On the edge of a grassy "opening" on Cove Mountain were a few medium sized colonies nesting in the soil under stones. The nests were shallow, and the soil surface beneath the stones was surrounded by an irregular sprinkling of fine dry soil particles.

Prenolepis imparis var. *testacea* Emery

This variety differs from the typical *imparis* in being yellow or reddish or brownish yellow, with the gaster and the posterior region of the head often darker and varying from light to dark brown. The legs are yellow.

Distribution.—Greenbrier Cove, 4200 ft.; near Gatlinburg (Talbot).

A group of four small nests of *testacea* was discovered beneath logs in a moist wooded area with rather loose soil. There was a sprinkling of fine soil particles beside each nest along the edge of the log.

Genus LASIUS (Fabricius) Mayr

The genus *Lasius* is an especially interesting one, and it is well represented in the Park, both in species and in the number of colonies. These ants can

be distinguished from members of the genus *Formica*, which they may rather closely resemble, by the second to the fifth joints of the antennal funiculus being shorter or not longer than the succeeding joints. The ocelli are usually absent, while in *Formica* they are distinct. There are two subgenera of *Lasius*, and these may be distinguished from one another by the key characters which follow.

The colonies are generally large. Most of the nests are subterranean—beneath stones, logs or small crater mounds—but a few are found in the interstices of decayed logs. The majority of the workers tends aphids on roots or on foliage above ground, deriving from them sweet exudates of which the ants are fond. The ants even collect eggs of aphids and store them in their nests during the winter. When these eggs hatch in the spring, the ants transport the young aphids to their food plants. While many of the species of *Lasius* are characteristic of bright, warm, well-drained places, some of them inhabit densely shaded woods and forests, where the soil is damp and cool. The following key will serve to separate the forms of *Lasius* in the Park:

KEY TO THE SPECIES OF LASIUS IN THE PARK

1. Maxillary palpi 6-jointed (*Lasius* s. str.) 2
   Maxillary palpi 3-jointed (subgenus *Acanthomyops* Mayr) 7
2. Last three joints of maxillary palpi elongated, of nearly equal length 3
   Last three joints of maxillary palpi short, successively diminishing in length 4
3. Scapes and legs with erect hairs ..... *niger* var. *neoniger* Emery
   Scapes and legs without erect hairs ..... *niger* var. *americanus* Emery
4. Tips of scapes not reaching to posterior corners of head ..... *brevicornis* Emery
   Tips of scapes extending beyond posterior corners of head 5
5. Tips of antennal scapes only slightly surpassing posterior corners of head; color pale yellow ..... *flavus nearcticus* Wheeler
   Tips of antennal scapes extending some distance beyond posterior corners of head; color brownish 6
6. Gaster subopaque, with appressed hairs..... *umbratus mixtus* var. *aphidicola* (Walsh)
   Gaster smooth and shining, without appressed hairs ..... *umbratus speculiventris* Emery
7. Penultimate joints of distally thickened antennal funiculi broader than long; gaster with abundant long hairs..... *claviger* (Roger)
   Penultimate joints of but slightly thickened antennal funiculi not broader than long; gaster with sparse long hairs..... *interjectus* Mayr

Lasius niger var. *americanus* Emery

This ant varies considerably in color, being from light to dark brown. The antennae and legs are without erect hairs. The ant is rather small, averaging about 3 mm. in body length.

Distribution.—Greenbrier Cove, 1500-1800 ft.; Chimneys camp ground, 3300 ft.; Wears Cove road, 1700 ft.; Cove Mt., 2000 ft.; near Tremont, 1700 ft.; Greenbrier-Brushy Mt. trail, 1800-3800 ft.; Davenport Gap, 2000 ft.; Little River Gorge, 1565 ft.; near Gatlinburg (Talbot), 1500-2000 ft. (Cole); Cades Cove, 1800 ft.; Gregory Mt., 2200 ft.; Greenbrier Pinnacle, 3800 ft.; near Cherokee Orchard, 1700 ft.

This—the so-called "cornfield ant"—is one of the most common members of the Park's ant fauna. It was found as high as 3800 feet, but is considerably more abunlant at the lower elevations. Especially in dry open areas, such as

sandy places, grassy fields and slopes or very open woods, its colonies were numerous in the soil beneath stones and logs and under bark of both logs and standing trees. Many nests were discovered in the open ground, unprotected by stones or woods; these were marked by small single or clustered earthen mounds. The colonies at the lower elevations were usually very populous. The ants of colonies inhabiting dry sunny areas were usually of a much paler color than those of dark forested places. Along the Ramsey Fork fire road, in Greenbrier Cove, the tiny mounds of sand were common at the lower elevations. The workers attend aphids on roots and stems of herbs and shrubs. The winged castes were numerous during the latter half of June at low elevations, and in July at higher ones. Both males and alate females were taken from nests on Cove Mountain, September 18, 1938.

Lasius niger var. *neoniger* Emery

This variety may be distinguished easily from *americanus* by the presence of erect hairs on the legs and antennal scapes. Its color varies from pale brown to dark brown. The body length is about the same as that of *americanus*.

Distribution.—Greenbrier-Brushy Mt. trail, 2500-4700 ft.; Ramsey Fork, Greenbrier Cove, 2700 ft.; near Gatlinburg, 2200-3500 ft.; Greenbrier Cove (Talbot); Indian Gap, 5200 ft. (Talbot); Chimneys camp ground, 3300 ft.

Nowhere abundant in the Park, this ant was collected at the higher elevations. Its nests, like those of *americanus*, were usually in the soil beneath stones or under bark or logs in rather open forests and grassy areas. They were shallow constructions, but consisted of many interconnected chambers. The colonies were frequently not so large as those of *americanus*. Alate females were collected by Miss Talbot on September 2, 1939, from nests in a grassy area near Indian Gap.

Lasius brevicornis Emery

This small yellow ant is very similar in general appearance to *L. flavus nearcticus*, but is of a dusky yellow color. The tips of the antennal scapes do not quite reach the posterior corners of the head.

Distribution.—Brushy Mt., 3800, 4900 ft.; Chimney Tops, 4756 ft.; Alum Cave, 4700 ft.

Nests of *brevicornis* were found only at the higher elevations, on heath balds and in pine-heath, and at but four places in the Park. On heath balds the surface soil was dry, warm and shaded only by the low scattered heath plants. On the Brushy Mountain heath bald colonies were very abundant in the soil beneath stones and old roots and stems, and were frequently associated with termite nests. The subsoil was moist, and beneath the crusty surface layer of peat the ants had constructed their small chambers and galleries to a depth of a foot or more. Most of the nests were against roots of mountain laurel and sand myrtle, where the workers attended root aphids and coccids. *L. brevicornis* is one of the predominant ants of the heath balds, and it together with *Brachymyrmex heeri depilis*, comprise the majority of the ant colonies in those places. It is, however, scarce in the pine heath. The colonies of

brevicornis are usually not large and consist at most of about one hundred individuals. Males and winged females were taken from nests on Brushy Mountain heath bald, September 22, 1937.

Lasius flavus nearcticus Wheeler

The body of this all-yellow ant is subopaque and rather densely pubescent, especially the gaster. The mandibular teeth are reddish brown. The length of the body is about 3 mm.

Distribution.—Greenbrier Cove, 1800-2500 ft.

A few small colonies were found in the moist shady cove hardwoods, and nested in the ground beneath stones and logs. The nests were shallow and the chambers few. The gasters of the sluggish moving workers have a milky white appearance.

Lasius umbratus mixtus var. *aphidicola* (Walsh)

The characters used in the key will serve to distinguish this ant from its close relatives.

Distribution.—Greenbrier Cove, 1800 ft.; (Talbot, Cole); near Gatlinburg, 1700 ft.

Nests were beneath stones in the cove hardwoods. The colonies were populous. The workers cultivate aphids on roots, around which they construct their galleries and chambers. Nests of this ant are not at all common in the Park and were discovered only at the lower elevations.

Lasius umbratus speculiventris Emery

This small ant has a body length of 3.5-4 mm. It is of a yellow color, with a densely hairy head, antennal scapes and tibiae. The head, thorax and legs are pubescent, while the gaster is smooth and shining.

Distribution.—Chimneys camp ground, 3300 ft.; Greenbrier Cove, 1800 ft.; Greenbrier-Brushy Mt. trail, 4000 ft.

Populous colonies were found in the soil under stones or in old logs and stumps in damp shady woods. The ant is rather uncommon in the Park. The nest extends for about a foot into the moist soil.

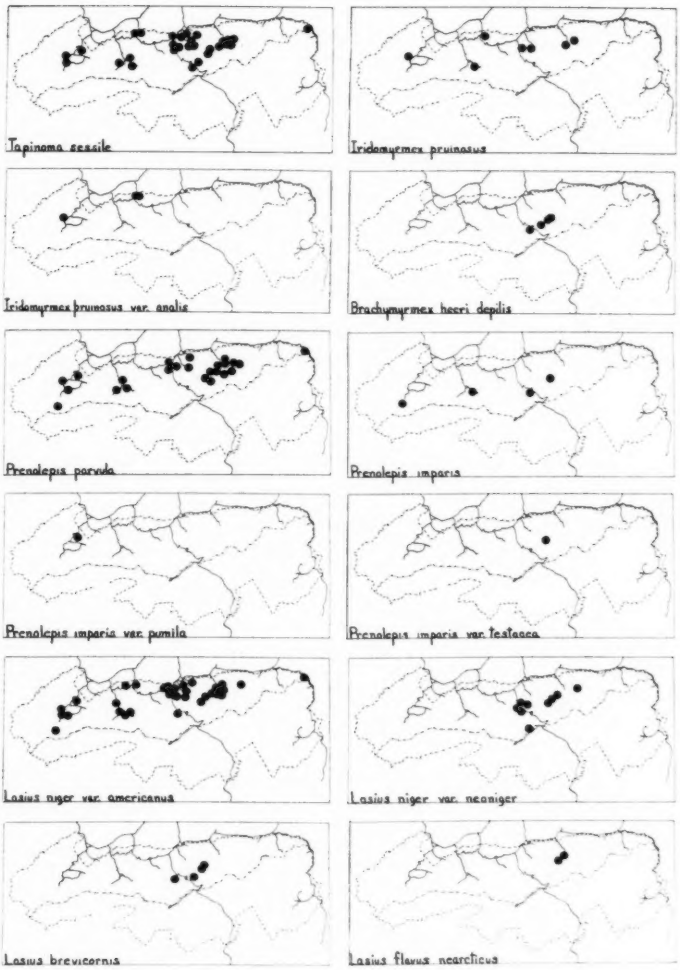
Lasius (Acanthomyops) claviger (Roger)

All the ants of the subgenus *Acanthomyops* have a characteristic odor of lemon verbena or oil of citronella, and all are yellow in color. *L. claviger* has abundant long hairs on the gaster. The body is about 4 mm. in length, shining and of a reddish yellow color.

Distribution.—Gregory Mt., 3000 ft.; Chimneys camp ground, 3300 ft.; near Gatlinburg, 1500 ft.; Cove Mt., 2000 ft.; Greenbrier Cove, 1800 ft.; Greenbrier Pinnacle, 3800 ft.

This is the most widely distributed species of *Acanthomyops* in the Park. Nowhere in the region is it common, however. It nests under stones in a variety of habitats, but usually in grassy places or along the edge of woods

PLATE 5


Tapinoma sessile
Tridomyrmex pruinosus
Tridomyrmex pruinosus var. analis
Brachymyrmex heeri depilis
Prenolepis parvula
Prenolepis imparis
Prenolepis imparis var. pumila
Prenolepis imparis var. testacea
Lasius niger var. americanus
Lasius niger var. neoniger
Lasius brevicornis
Lasius flavus nearcticus

where there are sufficient moisture and warmth. At such places in the Park its colonies were populous. Although this species was taken in the cove hardwoods forest-type, the nests there were small and the colonies weak. Isolated dealate females were occasionally found under stones during the winter months.

Lasius (Acanthomyops) interjectus Mayr

This is the largest species of the genus as represented in the Park. It looks very much like *claviger*, but the gaster is beset with sparse long hairs.

Distribution.—Gatlinburg, 2200 ft.; Greenbrier Cove, 1800 ft.

L. interjectus was found at but two localities, and at each of these the colonies were scarce. The ants nested in the soil beneath stones. The galleries extended from small superficial chambers beneath the stones to larger subterranean ones at a depth of approximately ten inches. These ants are also known to nest in or under old logs and stumps. They lead an entirely subterranean existence, and tend aphids and coccide on roots of plants. The colonies observed in the Park were populous and were all in rather open grassy places with occasional scattered trees.

Genus FORMICA (Linné) Mayr

This genus contains a rather extensive number of species, subspecies and varieties, and is circumpolar in extent. It includes small to medium-sized ant which, for the most part, live in large colonies. The forms differ greatly in habitat. Some are confined to arid regions in the southern and southwestern states, while others are essentially inhabitants of high elevations and are hence boreal in their range. Most, however, are characteristic of hilly or mountainous areas at moderate elevations. There they nest in open woods or on grassy slopes where rainfall is rather abundant and where there is sufficient sunshine during the summer. In such places also, there is usually an abundance of stones and slopes. In mountainous sections the species are numerous and the colonies populous; in hilly or rolling regions there is a similar but less pronounced number, owing probably to less favorable environmental conditions, such as those of temperature, moisture and vegetation.

Workers of *Formica* differ from those of other genera in the subfamily Formicinae in the following respects: The mandibles have broad dentate apical borders; the maxillary palpi are 6-jointed (very rarely 5-jointed), the fourth joint being not or but slightly longer than the fifth; the labial palpi are 4-jointed; the clypeus is trapezoidal and usually distinctly carinate; the clypeal and antennal foveae are confluent; the frontal area is usually very distinct; the frontal carinae are subparallel or diverging behind; the eyes are convex, moderately large and situated behind the median transverse axis of the head; the ocelli are always distinct; the antennae are 12-jointed, inserted near the posterior corners of the clypeus, with the funiculi more or less thickened apically but without a club; the thorax is distinctly and often deeply constricted in the mesoepinotal region; the epinotum is angular or rounded in profile and always unarmed; the petiole is scale-like, erect and compressed anterioposteriorly.

The female is generally noticeably larger than the worker, except in some

parasitic species where it may be of the same size as or even smaller than the largest worker. The genus is well represented in the Park by fifteen species, subspecies and varieties, and has a wide range of distribution by elevation. Nests are constructed, for the most part, in the soil beneath stones; but some species build earthen mounds or broad flat "beds." One species, *F. habrogyna*, frequently banks lightly with plant débris the stones covering its nests.

KEY TO THE SPECIES OF FORMICA IN THE PARK

1. Anterior border of clypeus notched or emarginate in the middle 2
   Anterior border of clypeus entire, rounded, or angularly produced in the middle.... 4
2. Frons and vertex more or less infuscated.....*sanguinea aserva* Forel
   Frons and vertex not infuscated 3
3. Gaster black; petiolar scale broad, with a sharp superior border usually notched in the middle .....*sanguinea rubicuda* Emery
   Gaster dark brown; petiolar scale with a blunt and usually entire superior border .....*sanguinea subintegra* Emery
4. Sides of head subparallel, posterior border deeply and broadly excised; basal border of mandibles with vestiges of teeth .....*exsectoides* Forel
   Sides of head usually converging anteriorly, posterior border straight or convex or at most very feebly excised; basal border of mandibles without vestiges of teeth 5
5. Body robust; head of largest individuals not or scarcely longer than broad; funicular joints 2-3 longer and more slender than joints 6-8; petiole usually with a rather sharp superior border; body opaque, color light or dark red with brown or black gaster; female not larger and sometimes even smaller than largest workers, measuring only 4-6 mm. .....*habrogyna* Cole
   Body more slender; head of largest individuals usually longer than broad; funicular joints 2-3 only slightly more slender than joints 6-8; petiole usually narrow, rather thick and with a blunt superior border; color and sculpture diverse 6
6. Thorax rather stout; median joints of funiculi less than 1½ times as long as broad; scapes stout, distinctly curved at base; petiole flattened behind..... 7
   Thorax longer and more slender; median joints of funiculi more than 1½ times as long as broad; scapes slender, scarcely curved at base; petiole convex behind 10
7. Gaster opaque or subopaque, densely pubescent 8
   Gaster somewhat shining, sparsely pubescent 9
8. Pubescence on gaster short, not silky .....*fusca* Linné
   Pubescence on gaster longer, denser, silky .....*fusca* var. *subsericea* Say
9. Body length of workers 6-8 mm., finely pubescent .....*lecontei* K. & D.
   Body length of workers 4-7 mm., more coarsely pubescent.....*fusca* var. *subaenescens* Emery
10. Erect hairs present on gula and petiole 11
    Erect hairs absent on gula and petiole 13
11. Gaster distinctly infuscated, darker than the head and thorax 12
    Gaster scarcely darker than the head and thorax, its pubescence longer and denser .....*pallide-fulva schaufussi* var. *dolosa* Whlr.
12. Hairs on gula and petiole numerous and conspicuous....*pallide-fulva schaufussi* Mayr
    Hairs on gula and petiole few, often lacking on one or the other; head, thorax and gaster often fuscous .....*pallide-fulva schaufussi* var. *incerta* Emery
13. Gaster dark brown or blackish, head and thorax light or dark brown or reddish....14
    Entire body reddish yellow.....*pallide-fulva* var. *succinea* Whlr.
14. Head and thorax light or dark brown or reddish, gaster dark brown or blackish .....*pallide-fulva nitidiventris* Emery
    Body dark reddish brown or blackish, anterior portion of head and the legs paler .....*pallide-fulva nitidiventris* var. *fuscata* Emery

Formica sanguinea aserva Forel

The worker measures 4-7 mm. in body length, and have the head and thorax brownish red and the gaster black. The posterior portion of the head, and often also the middle of the pronotum, is blackened. The head and gaster are rather shining. Hairs are usually absent on the thorax and petiole and short on the gaster.

Distribution.—Indian Gap, 5250 ft.

This is one of three of the slave-making ants known from the Park. Only one colony was found. The female raids colonies of *F. fusca* for pupae. The workers which emerge from these pupae aid in the establishment of the colony. The colony eventually becomes one purely of *aserva*, since the workers do not inherit the parent's slave-making instincts. The one found in the Park was rather small and contained both *aserva* and *fusca* workers. The nest was in the soil beneath a stone in the rich damp spruce-fir forest of Indian Gap. It consisted of three broad chambers, at a depth of about ten inches in the soil, connecting to the surface by a single gallery.

Formica sanguinea rubicunda Emery

The head, thorax and petiole are rather light red or reddish brown, the head is not darker than the thorax and the mandibles are little darker than the head. The gaster is black. Hairs are numerous on the upper surface of the head and on the pro- and mesonotum, and there are usually a few erect hairs on the petiolar border and on the gula. The body, especially the gaster, is shining.

Distribution.—Indian Gap, 5250 ft.

This ant is known as the "blood-red slave-maker" of the United States, or as the "sanguinary ant." In the Park it was found only at Indian Gap. Two nests were in the soil beneath stones on the edge of a recently cleared area forming an "island" in the spruce-fir forest. The stones were lightly banked along their edges with detritus. The workers and their slaves *(F. fusca)* were observed moving their brood from old nests in rather open forest to the new ones after recent heavy July rains. *F. sanguinea rubicunda* obtains slaves by pillaging colonies of *fusca* and kidnapping larvae and pupae. The colony is maintained as a mixed one, since slave raids are made periodically. The colonies become rather large and the older nests contain numerous chambers in the soil.

Formica sanguinea subintegra Emery

This ant is closely related to *rubicunda*. Like the other two forms of *sanguinea* in the Park, it possesses a notched clypeal border. It differs from *rubicunda* by having a brown instead of a black gaster. The reddish brown head, thorax, petiole and appendages are usually tinged with yellow.

Distribution.—Greenbrier-Brushy Mt. trail, 3000 ft.

Two nests of this ant were found in the Park. Both were on the ground under piles of dead leaves beside boulders in the cove hardwoods. There were

no nest chambers observed in the soil, but under the litter the brood was piled in natural pockets. Both colonies were large and contained much brood. The enslaved workers were those of *F. fusca* var. *subsericea*, and these represented about one-quarter of the mixed colony's numerical strength. A third colony was observed moving its brood from one nest to another, but the nests were not located. There are references in the literature to the propensity of *subintegra* for moving its colony from one place to another frequently. The queens establish their colonies much as do those of *rubicunda*.

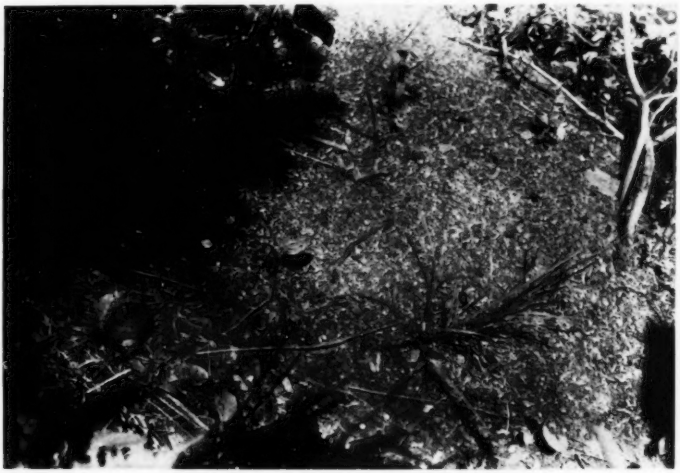


Fig. 17. Domed mound of *Formica exsectoides*. Photo by A. C. Cole.

Formica exsectoides Forel

This ant is of a deep red color and has a black gaster, the anal region of which is reddish. The mandibles, vertex, funiculi, legs and dorsal portions of the thorax are sometimes brownish or dark red. The head, thorax and petiole are subopaque or slightly shining, the gaster being more shining. Hairs are absent from the thorax, and are blunt and scattered on the gaster. The body length varies from 4.5 to 7.5 mm.

Distribution.—Brushy Mt., 3200, 3800 ft.

Several colonies of *exsectoides* (known as the Allegheny mound-building ant) were discovered in oak-pine and pine-heath forest types on Brushy Mountain. These had constructed dome-shaped mounds chiefly of plant debris. The mounds were from 6 to 10 inches in height and 3 to 5 feet in diameter, and were made loosely of fine pieces of dry twigs, earth and pebbles. All were in open areas between trees and exposed to the bright summer sunshine. Some of the mounds had originally been higher, but had been partially

leveled by rain and slope wash. The larger nests, which had numerous chambers both in the mounds and in the soil beneath to a depth of almost 3 feet, contained thousands of workers. The workers were very active and pugnacious, and attacked the intruder mercilessly. Always they swarm over the collector, tightly grasp an area of his skin between their mandibles and, by curling the tip of the gaster anterioventrally, eject a fine spray of formic acid from the tip of the gaster. The workers forage for dead insects and also tend aphids on the foliage of nearby trees. The brood is transported to the interstices of the mound during the warmer periods of the day, and is returned to the subterranean nest chambers for the night. A few incipient mounds were found near the large ones. Males and alate females were in nests in late June and early July, and a mating flight was witnessed on July 9, 1939. The nests contain several to many queens.

Formica habrogyna Cole

The body length is 4.3-6.1 mm. The head and thorax are brownish red and the legs and antennal funiculi are somewhat darker. The gaster is blackish brown except the base, which is reddish. The posterior portion of the head and the apex of the epinotum are usually lightly infuscated. This species is most easily recognized by the queen, which has the head and thorax of a beautiful uniform russet color and the gaster somewhat darker. She is smaller than the largest workers.

Distribution.—Near Gatlinburg,1700 ft. *(type locality);* Brushy Mt., 3500 ft.; Greenbrier Cove, 1800-2500 ft.; near Tremont, 1700 ft.

F. habrogyna nests in bright grassy places in the ground beneath stones. The periphery of the stone's impression occasionally bears a small amount of plant débris, but this is usually not observed until the stone has been removed. In the impression is a number of broad, variously and irregularly shaped mouths to the vertical galleries which extend underground to the many nest chambers. The depth of a typical nest is about 18 inches. The queen which, in the summer, can generally be found with the brood in a chamber about 3 inches beneath the surface of the nest, is superficially of a rather uniform reddish yellow color. She can, therefore, be seen readily. All the colonies found were rather populous. The workers are pugnacious, and eject formic acid when disturbed by the collector.

Since *habrogyna* was described only recently (Cole, 1939), I wish to add here some additional notes about it and its nests. Males and alate females were found in nests during June. The first males were taken June 10, and the first winged females June 17, 1939. Cocoons and workers were taken to the laboratory from a nest in Greenbrier Cove (1500 ft.), May 27, 1939. Males began emerging in the laboratory on June 4; but no females emerged. A nest, from which I had removed the queen on May 1, was abandoned completely by June 3. Workers and brood remained between these dates. The same or another colony was, however, under the stone on June 17. A queen could not be found.

On May 13, 1939, I brought to the laboratory for observation 9 cocoons

and 4 workers (2 major and 2 minor) from a paratype nest, and placed them together in a 6-inch shell vial with a moist cotton stopper. The major workers periodically moved the cocoons, which were always placed in a loose pile, over and over in the vial. Two cocoons molded, and they were transferred to the opposite end of the vial. The workers continually rubbed their antennae over the light-colored end of the cocoons. Just before a male was ready to emerge, a worker, examining the cocoon, would make rapid short jerky movements with its body, and would wave its antennae against the larger end of the cocoon. Then with its mandibles the worker cut a slit in the side of the cocoon very near the tip until the incision was large enough for the head of the male to protrude. The made would force its way out, stretching and rupturing the cocoon further. The attending worker would run its antennae over the male and then immediately feed it by regurgitation. Finally, the worker would aid in expanding and drying the wings of the male by using its antennae and mouthparts. Only a single worker opened a cocoon; there was no assistance from other workers. Each of the two major workers opened cocoons. The minor workers played no part in these activities. The experiment was repeated several times, and the results were the same. Checks were groups of cocoons without workers. These cocoons never emerged, and when I finally opened them, fully developed dead males were found.

Formica fusca Linné

The color of the body is black, and the mandibles, scapes, basal funicular joints and legs are deep red. The surface is subopaque with whitish, erect, short, very sparse hairs confined to the upper portion of the head and the thorax and gaster. The pubescence is dense but not silky on the head, thorax and gaster. The body is 4-6.5 mm. in length.

Distribution.—Mt. Le Conte, 6500 ft.; Clingmans Dome, 6600 ft.; Indian Gap, 5250 ft.

F. fusca is typically a resident of high elevations, replacing for the most part its varieties of the valleys and lower elevations in general. It is also a member of the ant fauna of north and central Eurasia and of the mountains of southern Europe, and is widely distributed in boreal America. Colonies found in the Park were rather small. They had constructed their nests in the soil beneath stones and logs of damp deeply shaded spruce and fir forests. Everywhere they were rather scarce, however. The nests consisted of several to many large and irregularly shaped chambers at a depth of from one to two and one-half feet in the moist soil. These connected by galleries to a few shallow surface chambers beneath the nest cover. The workers are extremely timid. Structurally, *fusca* is very similar to its varieties *subsericea* and *subaenescens* and to the species *lecontei*.

Formica fusca var. *subsericea* Say

The body is black with a faint metallic luster, and is a little more shining than the typical *fusca*. The antennae, mandibles, tarsi and articulations of the legs are brown. The pubescence is long and dense, making the body, and

especially the gaster, appear silky. It is dense but shorter on the scapes and legs. The body is 4-7 mm. in length.

Distribution.—Ramsey Fork, Greenbrier Cove, 2100 ft.; Gregory Mt., 2000 ft.; near Gatlinburg, 1500 ft.; Greenbrier Cove (Talbot).

Colonies were found in rather open sunny areas beneath large flat stones, in low flat "beds" and in earthen mounds two to three inches in height. They were populous, and usually were aggregated in the area. The beds and mounds both contained a huge number of openings through which the workers milled in and out. Some of these entrances connected by galleries directly with subterranean chambers, while others had been expanded in the bed or mound to form shallow surface chambers. For the most part, the beds and mounds were kept free of plants by the workers which, with mandibles and formic acid ejections, destroyed encroaching plant growth. Nests beneath stones and logs possessed a surface aspect of many shallow superficial chambers around which fine soil particles had generally been scattered by the ants. The stone or log was frequently margined with soil particles so as to form a partial bank.

Formica fusca var. *subaenescens* Emery

This black ant is very similar to *subsericea*, but the pubescence is much more sparse, so that the ground surface is plainly visible. The body has distinct bronzy reflections.

Distribution.—Greenbrier Cove, 1800-2500 ft.; Cove Mt., 2000 ft.; Chimneys camp ground, 3300 ft.; Alum Cave, 5000 ft.; Chimney Tops, 4756 ft.; Brushy Mt., 3800, 4900 ft.

This is the common black *Formica* in the Park, except at the lowest elevations. Everywhere along the trails the workers may be seen foraging. The nests are usually in the moist soil beneath flat stones in shady woods. A few colonies were discovered, however, nesting under the dry peaty surface soil at the Chimney Tops and Alum Cave. At these places a few small entrances broke the peaty layer. Other colonies nested in the earthen banks of the trails which were perforated with nest entrances. The colonies were populous and frequently contained thousands of workers. Nests usually extend to a soil depth of three or more feet. The nest surface beneath a stone was frequently marked only by scattered shallow excavations with entrances leading by galleries to deep subterranean chambers. Males and winged females were found in nests during June and July.

Formica lecontei Kennedy and Dennis

The workers of this species very closely resemble the larger ones of *fusca* var. *subaenescens*. The head and thorax are of a pure jet black color, and the gaster is nearly so. The mandibles, antennae and legs are dark brown. The body bears a delicate frosting of silvery pubescence. The larger individuals are about 7 mm. in body length.

Distribution.—Indian Gap, 5250 ft. *(type locality)*, (Kennedy, Cole);

near Grassy Patch, 4000 ft.; Greenbrier Cove, 4000 ft.; near Gatlinburg, 1900 ft.

Ants which appear definitely to be those of *lecontei* were collected at a few places in the Park, usually at high elevations. The mountain meadow at the type locality is now very much smaller than it was formerly. During construction of the new highway along the crest, much of the vegetation was destroyed, and the road now traverses what was once an expansive subalpine meadow. As a result, colonies of *lecontei* are scarce at that place. The ants construct large shallow nests beneath and around flat stones. The soil at the surface is mined with galleries, and the entrances to the nest are scattered over the soil of the loose earthen bed from which plants (chiefly grass) are not cleared by the workers. Beneath the stone is a number of shallow superficial chambers interconnected by undulating horizontal galleries which lead also to shallow subterranean chambers both beneath the stone and in the uncovered part of the nest. The basal nest chambers were at depths of 6 to 20 inches. The winged castes were in nests during June.

An aggregation of nests was discovered on a grassy slope near Grassy Patch. Each colony was beneath a large flat stone, in the manner described already. It is exceedingly difficult to distinguish the workers of *lecontei* from those of *fusca* var. *subaenescens*. When males of *lecontei* can be obtained the differences are more evident. They have the antennae of a medium brown color, whereas the antennae of the male of *subaenescens* are lemon yellow.

Formica pallide-fulva schaufussi Mayr

This ant is of a brownish yellow color, with the gaster infuscated and the mandibles red. The pubescence is rather long and distinct, especially on the gaster. The hairs are long and numerous on the head, gula, upper surface of the thorax and the petiole.

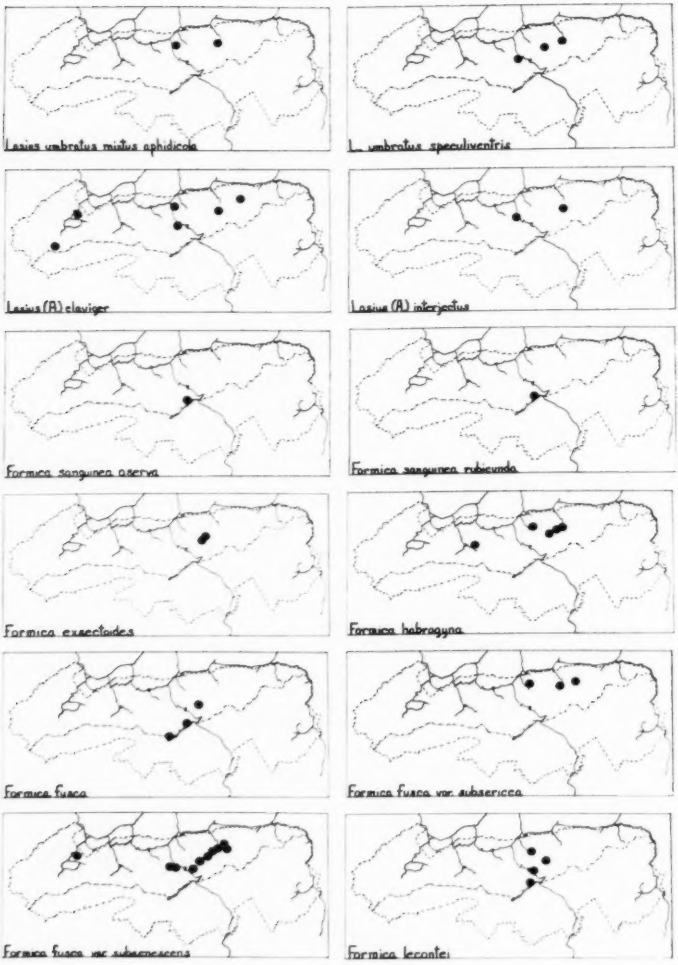
Distribution.—Brushy Mt., 3800 ft.; near Gatlinburg, 1500-2000 ft.; Greenbrier Cove (Talbot), 1800-2000 ft. (Cole); Cades Cove, 1800 ft.; Davenport Gap, 2000 ft.; near Tremont, 1800 ft.; Wears Cove road, 1700 ft.

This is a common *Formica* at the lower elevations, while a few nests were found at only a single place with a high elevation. On the grassy slopes near Gatlinburg colonies were particularly numerous. The ants live in the ground, as a rule beneath stones in open, warm, rather dry grassy areas. A few obscure crater mounds were found, and a number of colonies which nested beneath stones had adjoining earthen craters. The stones were loosely banked along their margins with soil particles. Underneath was a number of large, irregular superficial chambers, but the main part of the nest was at a depth of $1\frac{1}{2}$ to 2 feet underground. The colonies are, as a rule, populous, and the workers are agile and timid when disturbed.

Formica pallide-fulva schaufussi var. *dolosa* Wheeler

The color of the body is brownish yellow, and the gaster is only slightly darker than the head and thorax. The gaster is less shining than the rest of the body owing to the somewhat long and dense pubescence.

PLATE 6


Lasius umbratus mixtus aphidicola
L. umbratus speculiventris
Lasius (A.) claviger
Lasius (A.) interjectus
Formica sanguinea aserva
Formica sanguinea rubicunda
Formica exsectoides
Formica habrogyna
Formica fusca
Formica fusca var. subsericea
Formica fusca var. subaenescens
Formica lecontei

Distribution.—Greenbrier Cove, 1500-2000 ft.; Brushy Mt., 3800 ft.; Wears Cove road, 1700 ft.; Little River Gorge, 1500 ft.; Cove Mt., 2000 ft.; near Tremont, 1700 ft.; Davenport Gap, 2000 ft.; near Gatlinburg, 1900 ft.; Cades Cove, 1800 ft.

This ant is not uncommon in the Park. The colonies, which are far more numerous and populous at lower elevations, nest in the soil beneath stones in bright grassy areas or in open woods. The nest construction is like that of the typical *schaufussi*. Males and alate females were in the nests during June. A mating flight was observed at Greenbrier Cove on July 7, 1939.

Formica pallide-fulva schaufussi var. *incerta* Emery

This variety is very similar to the typical *schaufussi*, but the gular and petiolar hairs are few and often lacking on one or the other region. The color of the body is frequently a little darker than that of *schaufussi*.

Distribution.—Greenbrier Cove (Talbot), 1500-2000 ft. (Cole); near Gatlinburg, 1800 ft.

Colonies of *incerta* are numerous at lower elevations. The habitats and nesting habits are like those of the typical *schaufussi*. Males and females were in the nest during June.

Formica pallide-fulva var. *succinea* Wheeler

The body is shining, rather smooth and of a rich reddish yellow color. The pubescence is short and inconspicuous, especially on the head and thorax.

Distribution.—Cades Cove, 1800 ft.; Cove Mt., 2000 ft.

Two colonies of what appear to be those of *succinea* were discovered in the Park. The one at Cades Cove was in an area of old-field pine, while that on Cove Mountain was at the margin of a grassy opening of a second-growth pine forest. Both were beneath flat stones shaded by trees. There is a possibility of these ants' being the typical *pallide-fulva*, but they are distinctly of a pure reddish yellow color and not of the pale yellow so characteristic of the typical species.

Formica pallide-fulva nitidiventris Emery

The head, thorax, petiole and appendages are reddish brown or dark brown and the gaster is dark brown. The average size (4-6 mm.) is less than that of other forms of *pallide-fulva* except *nitidiventris* var. *fuscata*. The gula and petiole lack erect hairs. The pubescence is short and sparse, and hence the gaster is very shining.

Distribution.—Greenbrier Cove, 1600-3000 ft.; Brushy Mt., 3800-4900 ft.; Gregory Mt., 2200, 3000, 4900 ft.; near Gatlinburg, 1800 ft.; Cades Cove (Talbot).

Nests of *nitidiventris*, while not common, were found at a number of places beneath stones in shady areas of open woods and along the margins of woods. They are very similar to those of *schaufussi*, but the colonies seemed to be less populous. Several colonies were found in ditch banks along the

Greenbrier-Brushy Mountain trail. Males were in nests near Gatlinburg on June 17, 1939.

Formica pallide-fulva nitidiventris var. *fuscata* Emery

The body is of a dark reddish brown or brownish black color, with the anterior part of the head and the legs lighter. The tips of the funiculi are infuscated, and the mandibles, antennae, tarsi, tibiae and leg articulations are redor yellowish red. Hairs are very sparse on the head and absent from the gula and petiole and usually from the thorax.

Distribution.—Cades Cove, 1800 ft.

A few nests of *fuscata* were found in an old-field pine area at Cades Cove. They were beneath stones in the shade of trees. The nesting habits of *fuscata* are very similar to those of the typical *nitidiventris*.

Genus CAMPONOTUS Mayr

This genus includes our largest and most conspicuous, as well as many of our most abundant, North American ants. On a bilological basis, it may be divided into two large groups: those which nest in the ground beneath stones and logs, and those which live chiefly in dead wood, under bark of standing trees or in galls.

Camponotus may be distinguished from other genera of Formicinae in the Park by the great variation in the size of the workers which comprise a colony. Most of the workers are of at least two different sizes, while many of our species exhibit pronounced polymorphic workers. The smaller species belong to the Caryae Group, all of which are characterized by a distinct but narrow notch in the anterior median margin of the clypeus.

There is a number of species of *Camponotus* in the Park, including a few of the Caryae Group. Most of our representatives of this genus are large ants which live in logs or beneath stones, and some of them construct great numbers of nests which are met with commonly in the forested areas. These ants have not been found at the highest elevations, but are relatively numerous in places even at an elevation of 4000 feet. The species, subspecies and varieties inhabiting the Park may be separated readily by use of the following key:

KEY TO THE SPECIES OF CAMPONOTUS IN THE PARK

1. Anterior median clypeal margin with a distinct but narrow notch 2
   Anterior median clypeal margin entire, or at most very feebly eexcised or sinuate in the middle 4
2. Body black ..... *caryae* (Fitch)
   Thorax reddish brown 3
3. Head reddish brown like the thorax, gaster black throughout ..... *caryae* var. *decipiens* Emery
   Head large dark brown or black, gaster banded with yellow—*caryae* var. *pardus* Whlr.
4. Head small (3.2 x 2.8 mm.), body shining, mandibles 6-7 toothed 5
   Head large (3.4 x 3.4 mm.), head and thorax at least opaque or subopaque, mandibles 5-toothed 6
5. Body entirely yellow or reddish yellow ..... *castaneous* (Latr.)
   At least the head dark brown or black ..... *castaneus americanus* Mayr

6. Thorax, petiole, gaster and usually also the legs black, pubescence pale yellow or white ..... *herculeanus pennsylvanicus* De Geer
Posterior portion of thorax, the petiole, legs and base of gaster reddish brown or reddish yellow; pubescence and pilosity golden yellow ..... *herculeanus pennsylvanicus* var. *ferrugineus* (Fab.)

Camponotus caryae (Fitch)

The major workers vary from 7 to 9 mm. in length, and the minor workers from 4 to 6 mm. Most of the body is shining, but the head, especially in front, is subopaque. The head, thorax and gaster are black or piceous. The legs are brown or yellowish, and the posterior borders of the gactric segments are yellow.

Distribution.—Greenbrier Cove, 1800-2200 ft.; Brushy Mt., 3800 ft.; Greenbrier Cove (Talbot).

A few nests of *caryae* were discovered in the Park, and stray workers were collected at various places in Greenbrier Cove. At no place were nests abundant. In Greenbrier Cove colonies lived beneath bark of standing dead trees. In the Brushy Mountain pine-heath two nests were found under bark of partially decayed pine logs. One colony inhabited an abandoned hornet's nest in Greenbrier Cove. This species and its subspecies and varieties live in small colonies. The workers move rather agilely, and on warm days may be observed tunning over dead trees and posts and rails along the fire roads.

Camponotus caryae var. *decipiens* Emery

The head, thorax, petiole and appendages are brownish red. The gaster is black with pale yellow margins to the segments. Some specimens have the middle of the head and the anterior border of the genae dark brown. In the minor workers the posterior portion of the head is often deep red or brown, and the petiole is infuscated. The body length varies from 4.5 to 7 mm.

Distribution.—Greenbrier Cove, 2000, 2300 ft.

Two colonies of *decipiens* were found beneath the bark of standing dead trees in open woods. The nests were very much like those of *pardus*.

Camponotus caryae var. *pardus* Wheeler

Size varies from 3.5 to 6 mm. The thorax, legs, clypeus, cheeks, antennae and mandibles are of an ivory yellow color. The dorsal surface of the thorax has dark brown spots, and the legs and antennae are variegated with brown. The anterior portion of the head is brownish. This variety is highly variable in color. Some of the major workers have the gaster entirely black.

Distribution.—Greenbrier Cove (Talbot), 1800-2000 ft. (Cole); Davenport Gap, 2000 ft.; Cades Cove, 1800 ft. (Talbot, Cole).

Three small colonies of *pardus* were discovered in the Park. They had nested beneath bark of standing dead trees in open woods. The ants had mined into the more firm wood and had constructed galleries and a few shallow

chambers in the more decayed portions between the layers of annual growth. Strays were collected in Cades Cove and in Greenbrier Cove.

Camponotus castaneus (Latreille)

This large species (major worker, 9-10 mm.) is yellow or yellowish red in color with the thorax somewhat darker and the gastric segments sometimes rather brownish posteriorly. The entire body is shining.

Distribution.—Greenbrier Cove, 2000 ft.

Only one colony of this handsome species was found in the Park. Its nest was under and within a large log in the cove hardwoods, and contained about 200 workers together with a number of males and alate females on April 12, 1939. Most of the nest chambers and galleries were within the log near its base, but a few were just beneath the surface of the soil.

Camponotus castaneus americanus Mayr

The color of this subspecies is highly variable, being usually of a dusky yellow or brownish shade. The head is always black or dark brown. Body length is the same as that of the typical species.

Distribution.—Greenbrier Cove-Brushy Mt. region, 2000-4000 ft.; near Gatlinburg, 2000 ft.; Cove Mt., 2000 ft.; Gregory Mt., 1500-2100 ft.; near Cherokee Orchord, 1700 ft.; Cades Cove (Talbot), 1800 ft. (Cole).

Many nests of this ant were found, and almost all of them were at the lower elevations in the moist cove hardwoods. Each nest was in the soil beneath a flat stone. Under the stone was a number of superficial nest chambers and wide-mouthed galleries which led vertically to large subterranean chambers about two and one-half feet beneath the surface. Males and winged females were collected from nests on Gregory Mountain (1500 ft.), October 17, 1937, and at 2100 feet on the same date males were taken. Males were collected in Greenbrier Cove (3000 ft.), April 3, 1939, and at 2000 feet, May 7, 1939. Males and females were taken from nests on Cove Mountain (2000 ft.), October 7, 1938, and March 7, 1939. There is every indication, therefore, that the winged castes remain in the nests during the winter and spring. I have never seen a mating flight of these ants.

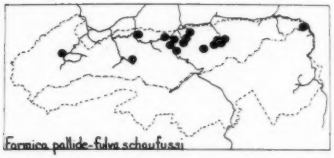
Camponotus herculeanus pennsylvanicus De Geer

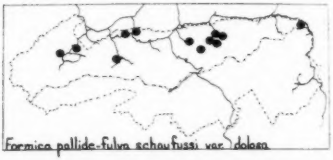
The body of this large ant (major workers, 10-13 mm.) is black, with the funiculi, tarsi and leg articulations usually reddish or dark brown. The head and thorax are somewhat shining, but the gaster is opaque and has extremely long dense pubescence which conceals the ground surface and presents a gray silky luster.

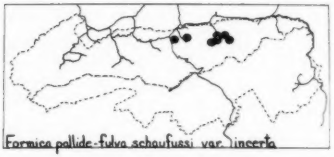
Distribution.—Greenbrier Cove-Brushy Mt. region, 1800-4200 ft.; Chimneys camp ground, 3300 ft.; Wears Cove road, 1700 ft.; Gregory Mt., 2200-4000 ft.; near Gatlinburg (Talbot); Cades Cove (Talbot); near Ramsey Cascades, 4200 ft.; Davenport Gap, 2000 ft.; Cove Mt., 2000 ft.

This so-called "black carpenter ant" is certainly not common in the Park,

PLATE 7


Formica pallide-fulva schaufussi


Formica pallide-fulva schaufussi var. dolosa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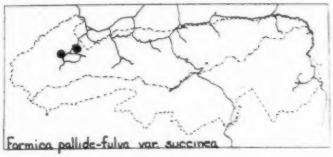
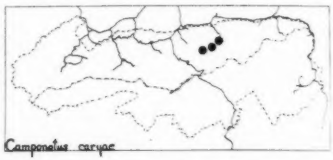
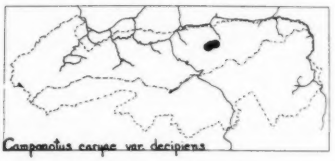
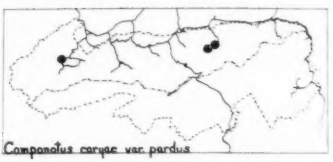
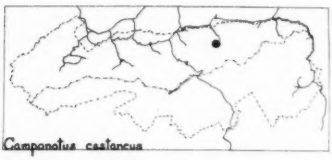

Formica pallide-fulva var. succinea

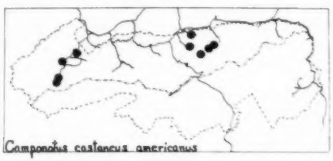
Formica pallide-fulva nitidiventris

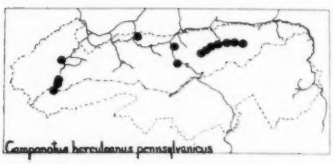

Camponotus caryae

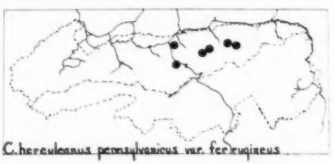

Camponotus caryae var. decipiens


Camponotus caryae var. pardus


Camponotus castaneus


Camponotus castaneus americanus


Camponotus herculeanus pennsylvanicus


C. herculeanus pennsylvanicus var. ferrugineus

although it presents a rather wide range. It nests in logs and stumps, which are in the early stages of decay, on the floor of open to dense woods. It is scarce at the higher elevations, and at 4000 feet in the Greenbrier-Brushy Mountain region only a few small colonies were found. These were in the hemlock ridge forest-type. Colonies were scarce also in the cove hardwoods forest on Gregory Mountain (4000 ft.). They were comparatively numerous, however, in the cove hardwoods forest at about 2000 feet.

Camponotus herculeanus pennsylvanicus var. *ferrugineus* (Fabricius)

This variety closely resembles the typical *pennsylvanicus* but differs in color. The thorax, coxae, femora, petiole and the base of the first gastric segment are red. The anterior border of the head and the tibiae and tarsi are deep red, while the black antennal scapes are tipped with yellow or red.

Distribution.—Greenbrier-Brushy Mt. trail, 2400, 3600 ft.; Ramsey Fork, Greenbrier Cove, 2200-4200 ft.; Cove Mt., 1900-2000 ft.; Wears Cove road, 1700 ft.; Chimneys camp ground, 3300 ft.; near Gatlinburg (Talbot); Greenbrier Cove (Talbot).

This variety is far more common than the typical subspecies in the Park. It is especially abundant at lower elevations in stands of open forest. At 4200 feet collections were infrequent, and colonies were not found above this point. The logs, in which the nests were always situated, were pretty well mined with tunnels and chambers, especially just beneath loose bark on the sides. At low elevations colonies were large, at high elevations small.

Glossary

Boreal, pertaining to the north; a life region extending from the Arctic southward to about the boundary of the United States and Canada and still farther southward in the high mountain ranges.

carina (pl., *carinae*), a ridge or keel.

circumpolar, surrounding a pole.

clypeus, that part of the head below the frons, to which the upper lip is attached.

confluent, running together.

cordiform, heart-shaped; triangular, with the corners of the base rounded.

coxa (pl., *coxae*), the basal segment of the leg, by means of which it is connected to the thorax.

dorsal, pertaining to the upper surface.

elliptical, oblong-oval; the ends equally rounded.

emarginate, notched.

endemic, peculiar to a region.

epinotum, the propodeum; that segment of the abdomen which is fused with the thorax.

excised, with a deep notch or cleft.

femur (pl., *femora*), the segment of the leg articulated with the trochanter basally and with the tibia apically.

ferruginous, *ferrugineous*, rusty reddish brown.

fossa (pl., *fossae*), a pit.

frons, the upper anterior portion of the head.

frontal area, a small usually triangular region in the middle line just above or back of the clypeus.

frontal carina, a ridge on the inner side of the insertion of each antenna.

frontal furrow, an impressed longitudinal line, posterior to the frontal area, which runs backward toward the median ocellus.

funiculus (pl., *funiculi*), the portion of an antenna connecting basally with the elongate first segment or scape; all of the antenna excepting the scape.

fuscous, dark brown, nearly black.

gaster, a group of abdominal segments, usually ovoid or globular, posterior to the pedicel or petiole.

gastric, pertaining to the gaster.

gena (pl., *genae*), the cheek; that part of the head on each side of the clypeus extending between the eyes and the mandibles.

glabrous, smooth and hairless.

gula, the throat; the ventral surface of the head posterior to the labium.

gular suture, a longitudinal suture dividing the gula.

hypogaeic, subterranean.

mesoepinotal impression, a suture separating the mesonotum from the epinotum.

mesonotum, the upper surface of the second or middle thoracic segment.

Mesozoic, Tertiary; a geologic era in existence about 60 million years ago.

nodiform, in the form of a knob or knot.

ocellus (pl., *ocelli*), simple eye; three of these small single lenses are arranged in a triangle on the vertex.

occiput, the back of the head between the vertex and the neck.

occipital margin, the posterior margin of the head.

opaque, without luster, not shining.

Palaearctic, a faunal realm including Europe, Africa north of the Sahara and much of Asia.

palpus (pl., *palpi*), a feeler-like structure of the mouthparts.

pectinate, comb-like; with even processes like teeth of a comb.

pedicel, one or two segments of the abdomen between the gaster and the epinotum.

peduncle, the pedicel.

penultimate, next to the last.

petiole, a pedicel formed of only one segment, or the first segment of a two-jointed pedicel.

piceous, pitchy black.

pilosity, the body covering of erect or suberect hairs.

Pleistocene, a geological epoch in existence about one million years ago, during which there was widespread glaciation.

postpetiole, the second or posterior segment of a two-jointed pedicel.

promesonotal impression, a suture separating the pronotum from the mesonotum.

pronotum, the upper surface of the first thoracic segment.

prosternum, the lower surface of the first thoracic segment.

pubescence, a coating of fine hair or down.

punctate, beset with punctures.

relic, a living representative of a group which had formerly a wider geographical distribution; a remnant.

reticulate, covered with a net-work of fine lines; meshed; netted.

ruga (pl., *rugae*), a wrinkle.

rugose, wrinkled.

scale, an elevated dorsal portion of the pedicel.

scape, the first antennal segment, articulated basally with the head and apically with the funiculus.

spatulate, rounded and broad at the top and tapering at the base.

spine, an unarticulated horn-like outgrowth of the body wall.

spur, an articulated spine-like process.

subopaque, nearly opaque but with a faint luster.

tarsus (pl., *tarsi*), the jointed part of the leg connected to the apex of the tibia, bearing the claws.

tarsal claw, the clew at the apex of the tarsus.

Tertiary, Mesozoic; a geological era in existence about 60 million years ago.

tibia (pl., *tibiae*), the fourth joint of the leg, between the femur and the tarsus.

thorax, the central body region, between the head and the abdomen.

Transition Zone, a transcontinental belt in which the austral and boreal elements overlap.

tuberculate, covered with small solid pimples.

ventral, the lower surface.

vertex, the top of the head between the eyes, frons and occiput.

vestigial, very small or degenerate; the remains of a previously larger structure.

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A Collection of Ants from Southcentral Ohio[1]

Laurence G. Wesson, Jr. and Robert G. Wesson

The following paper is a report on a collection of ants made by the authors during the summers of 1934-39 in southcentral Ohio. Almost all the work was done within 45 miles of Jackson. In it are listed 97 different forms together with such biological notes as seem significant. One variety of *Leptothorax* is described as new: *L. ambiguus* Emery var. *pinetorum*. The genus *Strumigenys* was dealt with in a previous paper,[2] and is listed here by species only.

The area in which the collecting was done lies almost entirely in the non-glaciated, dissected portion of the Appalachian plateau. Only in the northwest corner are there glacial drifts and broad, level areas. The surface strata vary widely. In the east they are largely shale and clay, and the hills are gentle and more heavily vegetated. In the central portion, sandstones and conglomerate predominate causing the hills to be steeper, flattened on top, better drained and less densely vegetated. In the western portion, where limestone is the dominant formation, the hills are lower, the soil shallow and rocky, and the vegetation quite variable.

The varied topography and surface strata of the region combined with various kinds and degrees of land utilization furnish a great variety of habitats. In order to present a general conception of the dominant ant fauna of this region before proceeding to a more detailed report of the particular species, we attempt a rough summary of the commoner species in the broader types of habitats. Nearly everywhere are found *Tapinoma sessile, Lasius americanus, Paratrechina parvula, Crematogaster lineolata, Solenopsis molesta,* and *Ponera pennsylvanica,* all except the *Ponera* being more abundant in drier and more open localities. In dry, upland fields are *Dolichoderus beutenmuelleri, Pheidole tysoni, Aphaenogaster treatae, Monomorium minimum. Formica schaufussi* and *Leptothorax pergandei* prefer the more barren spots while *Farmica nitidiventris* nests in more thickly vegetated places. *Leptothorax ambiguus* is found in grassier areas, especially those bearing beard grass *(Andropogon). Formica exsectoides* and *F. rasilis* are more abundant in the vicinity of scattered shrubs or small trees. On the moister hillsides, where grazing prevents weeds and brambles from growing, *Formica nitidiventris, Myrmica americana, Aphaenogaster aquia* and *Pheidole pilifera* appear in greater abundance. The open bottom meadows are characterized chiefly by *Myrmica americana* with occa-

1 We wish to express here our gratitude to Dr. M. R. Smith, U. S. Dept. of Agriculture, and Dr. W. S. Creighton, College of the City of New York for their valuable assistance with the taxonomy; and to Mr. and Mrs. E. B. Matthews of Jackson, O., who furnished the facilities which made our work possible.

2 Wesson, L. G., Jr., and R. G. Wesson, Notes on *Strumigenys* from Southern Ohio with Descriptions of Six New Species. Psyche **46**:91-112, 1939.

sional *Formica nitidiventris*. Dry hillsides covered principally with oaks have *Formica subsericea* and often the associated *F. subintegra* and *F. rubicunda*, *Brachymyrmex depilis*, *Lasius nearcticus*, *L. aphidicola*, *Prenolepis imparis*, *Camponotus americanus*, *Myrmica punctiventris*, *Leptothorax curvispinosus*, and its enslaver, *Harpagoxenus americanus*, *Myrmecina graminicola*. In clearings, along the edge of, or in broken woods, *Formica nitidiventris*, *Aphaenogaster treatae* and *Myrmica emeryana* are common in addition to the preceding forms; in woods in which the soil is very poor and rocky *Camponotus castaneus* replaces *C. americanus* in abundance; *Myrmica pinetorum* is abundant in pine woods and dry oak openings. On lower, somewhat moister but not too densely wooded slopes *Formica subsericea*, *Brachymyrmex depilis*, *Prenolepis imparis*, *Lasius aphidicola*, *Leptothorax curvispinosus*, are still present, while *Camponotus ferrugineus*, *C. subbarbatus*, *Dolichoderus plagiatus*, *Aphaenogaster aquia*, *A. rudis*, *Stenamma brevicorne* become common. In low moist woods *Lasius americanus*, *Prenolepis imparis* and *Aphaenogaster picea* are the principal ants found.

The most uniform and circumscribed habitat group we have found is that of the ants which nest in the crowns of trees, especially large white oaks. This comprises *Camponotus pennsylvanicus*, *C. nearcticus*, *Leptothorax schaumi* and *L. fortinodis;* frequently *Camponotus cnemidatus*, *Aphaenogaster mariae*, *Leptothorax wheeleri* and *L. curvispinosus* var.; *Aphaenogaster rudis* and *A. tennesseensis* sometimes nest in the lower parts of the trunk.

Ponerinae

Stigmatomma pallipes (Haldeman)—Found occasionally under stones or logs, usually in rather moist or shaded situations. Six workers were once observed about a large dead centipede. Males were taken in the nest early in September.

Sysphincta pergandei Emery—We have taken 3 single workers and a colony of this species. One worker was found in clay soil on the edge of a pasture under a stone under which ran numerous galleries of *Lasius aphidicola*. A worker was taken in a clearing in dry woods on clay soil under a punky pine log. Also under the log, near where the *Sysphinctas* were found, was a colony of *Lasius aphidicola*. Digging around the spot failed to reveal additional specimens. A worker was taken under a stone on shallow clay soil among some small pines and oaks. Under the stone were some deserted galleries of *Aphaenogaster aquia*. A colony, comprising a queen, 11 workers and 8 males was found in late August in dense oak woods under and scattered among the leaves surrounding a stone which also sheltered a colony of *Camponotus castaneus*. Thinking that there might be some relationship between the *Sysphincta* colony and the *Camponotus*, we put the former, together with workers and brood of *C. castaneus*, in an artificial nest so constructed that the *Camponotus* could not enter the *Sysphincta* chamber while the latter were free o go among the *Camponotus*. The *Sysphincta* went freely around in the *Camponotus* chambers, but seemed to avoid the open places and the brood. The *Camponotus* workers paid little attention to the intruders, but when one did on

occasion snap at a *Sysphincta*, the latter merely remained quiet until the attack passed. On the other hand, the *Sysphincta* workers were continually fighting among themselves, and once the queen was observed attacking a worker. This fighting resulted in 3 deaths in a few days. Frequently, a *Sysphincta* worker would approach another, give a little tug on its mandibles, whereupon the first worker would turn about and start off closely followed by the second. Such pairs would meander considerable distances but seemed to have no real goal. Attempts to feed the *Sysphinctae* on insect food met with little success. They refused to accept living or dead insects, with the exceptions noted below, appearing to be frightened by them. They likewise refused pupae of *Formica nitidiventris*. They were, however, seen to eat the inside of the gaster of a dead *nitidiventris* worker which had been offered them, and later did the same to a dead *F. fusca* and *Camponotus castaneus*. These observations, while quite inconclusive, suggest that *Sysphincta* may live, in part at least, on dead or dying ants.

Two of the single workers differed from the other collections and from Emery's figure of the species[3] in having the head, excluding the mandibles, as broad as long, with the posterior border broadly and evenly rounded; the first gastric segment shining above; the second gastric segment compressed dorsoventrally and elongate, the length 1.6 x the greatest thickness.

Proceratium silaceum Roger—On each of the seven occasions that we have taken this species, it has been in open woods in a stump or log that was well decayed superficially and kept moist by a protective layer of bark. A single colony, taken in mid August, comprised 40 workers, several winged males and females, 3 cocoons, 3 naked pupae and about 20 small larvae. In an artificial nest, one of the dealated females remained near the brood while the other roamed like a worker.

Proceratium crassicorne Emery—In contrast to the preceding species, we have occasionally (4 times) taken this ant in rather dry soil under stones or moss in open woods. One worker was taken in a rotten pine log in a clearing among grass and scattered bushes. A colony comprising 30 workers, a dealated female, about 8 males, 2 cocoons, 5 naked pupae and a few small larvae was taken in mid August from the soft, punky portion of a rotten log. In the artificial nest, workers of both this and the above species constructed neat, oval chambers from the crumbled rotten wood offered them. They ran actively about, but showed little interest in any form of food offered them. This may have been due to the lateness of the season, however.

Ponera coarctata pennsylvanica (Buckley)—Very common and widely distributed. In low moist woods, colonies are to be found in logs and stumps or in the humus. In drier woods and in fields, colonies are often found under stones as well.

Ponera trigona var. *opacior* Forel—Much less common than the above

3 Emery, C., Beiträge zur Kenntniss der Nordamerikanischen Ameisenfauna. Zool. Jahrb. Abth. Syst. 7:633-682, 1893.

species, taken in fields or dry woods under stones. A few workers were found in a rotten stump in partial shade.

Ponera oblongiceps M. R. Smith—A few workers of this species were found under a stone in partial shade, on moist but well drained soil, in Jackson.

Myrmicinae

Myrmecina graminicola americana Emery—*Myrmecina graminicola americana* var. *brevispinosa* Emery—Taken rather often in dry or open woods, the single workers being found on the ground under leaves or grass. Males have been taken at the end of August. Our material shows considerable variation in size, coloration and length of spines, although workers in each colony vary much less among themselves than do workers from different colonies. In general, the material varies between small brownish forms, small black forms and large black forms. The length of the spines is quite variable in all three forms. Small pale workers with short spines are referable to var. *brevispinosa*, but, in our opinion this variety is hardly separable from *americana*.

Monomorium minimum (Buckley)—Very abundant in sunny places and scattered woods.

Solenopsis molesta (Say)—Very abundant; found in rotten logs and stumps and under stones in woods and fields. Colonies of this species are often exposed while excavating the nests of other ants. One group of workers, taken on a moist wooded ridge in Jackson County, differ from the typical *molesta* in their smaller size and darker color which is brown.

Solenopsis laeviceps Mayr*—A single colony, apparently referable to this species, was found under a stone on an open, grassy, bushy hillside in Gallia County.

Solenopsis texana carolinensis Forel—Less abundant than *molesta* but found over a similar range of habitat. Like *molesta*, it is often lestobiotic.

Pheidole pilifera (Roger)—Fairly common in both dry and moist fields and meadows where the sun reaches the soil. One colony was taken in a small opening on a moist slope in the woods.

Pheidole tysoni Forel—Very common in dry fields and meadows and grazed hillside pastures; found occasionallyin openings in the woods. Winged females were taken in the middle of July.

Pheidole vinelandica Forel—Found in the same type of situations as *P. pilifera*, but apparently occurs much more sporadically. However, where we have found it, it is very abundant. Nearly all our scattered records are from south of Jackson. Numerous colonies of this species were found on a low,

* Identification verified by Dr. W. S. Creighton. Specimens of this species collected at Baton Rouge, La. in 1928 are in the Wheeler Collection (unpublished records).

sandy elevation bearing beard grass, cactus *(Opuntia)* and yucca, and fronting the Ohio river in southern Adams County. Here workers from a few of the colonies were pale brownish-yellow in color in contrast to the dark-brown color of the workers in the majority of colonies. Winged phases were taken in the middle of July.

Crematogaster lineolata (Say)—Very common in all but the most dense and moist woods. Colonies inhabit dry logs, sticks or stumps and are often found nesting under stones, especially in fields. They appear strongly polydomous. One nest of this species was built almost entirely of carton. The ants had constructed a thick, flaky and rather fragile carton between the diverging stems of a loose clump of beard grass in an open meadow. The nest was built in the form of an upright cigar-shaped structure about 18 cm. high, bluntly pointed above, about 10 cm. in diameter at the widest point a little below the middle and with the narrower bottom resting in the middle of the base of the clump. Within the nest was a dense tangle of stems and blades with occasional small bits of irregular, partitioning carton. Our specimens vary from large forms, 3.8 to 4.0 mm. long, with red, lightly sculptured thoraces, to small forms, 2.5 mm. long, with very coarsely sculptured, nearly black thoraces. Such a range of variation is not present in workers from the same colony, however. The large, paler forms seem to be much more abundant in open woods than elsewhere; the smaller, darker forms are common in both woods and fields.

Stenamma brevicorne Mayr—Found occasionally under leaves and debris in moist woods. We have not taken either this or the next species under stones.

Stenamma brevicorne schmitti Wheeler—Found on 4 occasions under leaves in woods. It apparently prefers somewhat drier situations than the preceding form.

Aphaenogaster mariae Forel—A member of the tree crown fauna, this species was taken frequently in oak trees, often high above the ground. It nests in small stobs or in rotten cavities under the bark. Winged prases were taken in a nest in mid July.

Aphaenogaster treatae Forel—Common everywhere in dry fields and open, well drained woods. Sometimes a small, irregular mound is piled outside the nest entrance. Winged females were taken from a nest in September.

Aphaenogaster treatae pluteicornis G. C. Wheeler and E. W. Wheeler—We have found this form widely distributed but uncommon. Two workers were taken in a fairly moist pasture. The 4 other collections were from rather dry, broken woods where the soil is poor. A colony from Meigs County contained 40 workers of the typical tawny color, while 20 workers were nearly black in color. The female was dark-brown.

Aphaenogaster fulva Roger—*Aphaenogaster fulva aquia* (Buckley)—*Aphaenogaster fulva aquia picea* Emery—Very common in and on the edge of woods. Our specimens vary from forms with yellowish-red or russet head

and thorax, heavier sculpture and numerous transverse rugae on the mesonotum *(fulva);* to forms with russet thorax, darker head, lighter sculpture, few or no transverse rugae on the mesonotum *(aquia);* to uniformly dark-brown forms with still lighter sculpture *(picea).* Between these we find all intergradations, although the workers from a given colony are fairly uniform. The females exhibit similar variations. Colonies of *fulva* seem to be most abundant in dry oak woods where sometimes nearly every stone shelters a colony. *Aquia,* the intermediate form, is more generally distributed, and is most abundant in moister and more open woods. *Picea* is taken commonly in dense or moist woods.

Aphaenogaster fulva var. *rudis* Emery—Taken frequently in well drained woods. The colonies are occasionally found in the soil and under stones, but more often in moist, well rotted logs and stumps. On one occasion, a colony was found in a moist rotten portion of a large oak branch about 2½ m. above the ground. Winged phases were taken from a nest in the middle of July.

Aphaenogaster tennesseensis Mayr—Often found nesting in logs, stumps and cavities at the base of trees in and on the edge of woods. Winged forms were taken in the nest in the middle of July.

Myrmica punctiventris Roger—Common in dry woods. This and the following form nest in very small colonies in the soil. We have never found them under stones. The nest entrance is often surmounted by a turret of crude carton.

Myrmica punctiventris pinetorum Wheeler—Common in pine woods on sandy soil. The colonies build carton turrets from the soil up through the pine needles.

Myrmica sabuleti americana Weber—Found in open fields and meadows and along the edge of woods. It is most abundant in moist and at the same time sunny situations.

Myrmica schencki emeryana Forel—Found rather often along the edge of, or in dry, open woods.

Myrmica lobicornis fracticornis Emery—We have taken this species occasionally in low, moist sunny spots, on the edge of woods or among scattered trees, and on the edge of dry fields. This and the two preceding species nest in the soil although rarely under objects.

Leptothorax duloticus Wesson—Three colonies were taken in the type locality, a steep, dry oak woods in Jackson County. The habits of this slave-maker are described in a separate paper.[4]

Leptothorax schaumi Roger—*Leptothorax fortinodis* Mayr—*Leptothorax fortinodis* var. *melanoticus* Wheeler—To this group belong more than 35 colonies and many stray workers, all collected from living or recently felled trees, especially oak. We have yet to find a large oak tree which does not have colonies of at least one of these forms on it. The nests are located in cavities in the bark or dead stobs. The colonies fall into 3 groups, as follows:

[4] Wesson, L. G., Jr., Observations on *Leptothorax duloticus* Wesson. Bull. Brooklyn Ent. Soc. In press. 1940.

1) *Yellow form.*—Seven of our colonies were found to contain only yellow individuals. Among these colonies, the coloration of the workers varies from pale yellow to a dark yellow with the gaster infuscated. The epinotal spines, even in workers from the same colony, vary from 1.5 to 0.66 times as long as broad at the base. The sculpture also is variable, being distinctly coarser and more rugose, especially on the thorax, in some specimens than in others. The relative sizes of the petiole and postpetiole vary distinctly, although not greatly. In all specimens, the petiole is at least slightly larger in profile than the postpetiole.

2) *Black form.*—In 20 colonies, the gaster of the workers is shining black and the color of the thorax ranges from a dull red to black among different colonies. With these, the same variations hold as with the yellow colonies; sculpture, color of the thorax and size varying distinctly among workers of the same colony, but not so markedly as between workers of different colonies. We have found little or no correlation between color, size, and length of spines. The comparative sizes of petiole and postpetiole are as in the yellow colonies.

3) *Mixed yellow and black form.*—Eight of the colonies contain both yellow workers and black workers, recalling the condition described by Wheeler[5] for *L. fortinodis* var. *gilvus*. We are completely unable to distinguish the two worker phases from one another and from the workers of the pure yellow or pure black colonies by any other character than the color. These mixed colonies are composed as follows:—

A) 1 yellow dealated female; 35 yellow workers; 30 black workers; 8 black alate females; 3 yellow alate females; 1 alate yellow female with infuscation on the head and thorax.
B) 1 yellow dealated female; 65 yellow workers; 60 black workers; 27 black alate females; 12 alate yellow females.
C) 1 yellow dealated female; 1 black dealated female; 2 yellow workers; 1 black worker; 1 worker with dark yellow head and thorax and black gaster.
D) 1 yellow dealated female; 4 yellow workers; 7 black workers.
E) 1 yellow dealated female; 6 yellow workers; 1 black worker.
F) 1 yellow dealated female; 14 yellow workers; 16 black workers.
G) 1 yellow dealated female; 30 yellow workers; 19 black workers; 1 black alate female; 3 yellow alate females.
H) 3 yellow dealated females; 25 yellow workers; 5 black workers.

After careful examination of series of males, females and workers from yellow, black, and mixed color colonies, we have been unable to find any difference other than color between them carrying the slightest consistency. Aside from this difference, yellow workers often resemble black workers more than they do others in their own colony. Although we have not examined type material of either *schaumi* or *fortinodis*, we have referred the yellow colonies to *schaumi* and the dark colonies to *fortinodis*. But until more satisfactory separatory characters are found, we regard *schaumi* and *fortinodis* as two color races or strains of a single species, which by priority should be *Leptothorax schaumi* Roger. *L. fortinodis* then would become *Leptothorax*

5 Wheeler, W. M., A Revision of the North American Ants of the Genus *Leptothorax* Mayr. Proc. Acad. Nat. Sci. Phila. **55**:236. 1903.

schaumi var. *fortinodis* Mayr. Since attempts on our part to distinguish *L. fortinodis* and var. *melanoticus* have given only arbitrary results, we have preferred to include *melanoticus* with *fortinodis*, regarding the two forms as described as representing the ends of a single color series which are not separable on a geographic or ecologic basis.

We follow Wheeler[5] in regarding the colonies containing workers of both colors as hybrids between the black and yellow forms. This is supported by the facts that 1) both black and yellow individuals continued to appear in nearly equal numbers in a colony in an artificial nest a year after the colony was discovered, although there was only a single yellow female present; 2) in only one instance (colony *c*) have we found dealated females of both colors in the nest; 3) two individuals with reversed coloration were found in the mixed colonies: the alate female in colony *a*, and a worker from colony *b* which was colored brown on the head and thorax and yellow on the gaster and which died soon after emerging from the pupal state. Since in none of these probable hybrid colonies have we found only a black female, and always a yellow female, it would appear that black is a dominant character, and that therefore at least some of the yellow workers in the mixed colonies must be produced parthenogenetically. The crossing of a male from a yellow colony with a female from a black colony would produce only black workers, masking the hybrid nature of the resultant colony.

Leptothorax wheeleri M. R. Smith—We have found many colonies of this species in galleries in the hardened, weathered logs on old deserted and tumbledown log cabins exposed to the sun. Two other colonies were found on large oak trees where they were nesting in dead stobs. On one occasion, workers were observed feeding on the exuviae of wood-boring beetles. Winged phases were taken in the early part of August.

Leptothorax longispinosus Roger—Colonies of this species are found locally abundant in open woods, and in crevices and under moss and lichen on dry boulders or rock outcrops. We have also found colonies nesting in hollow nuts and acorns on dry wooded hilltops, and in the bark at the base of trees. Winged phases were taken in early July.

Leptothorax curvispinosus Mayr—Found abundantly in and on the edge of woods except the very dense and moist. Here it nests on the ground in hollow stems, twigs, nuts, acorns and galls.

We have taken five colonies of an interesting variety of this species from dead twigs or cavities in the bark of living or recently felled oak trees. In all cases, the colonies have been located many feet from the base of the tree. The workers differ from the worker of the typical *curvispinosus* in (1) the short epinotal spines which vary from as long as broad to twice as long as broad at the base; (2) the less convex posterior slope of the petiole; (3) the more uniform rugosity on the sides and dorsum of the thorax; (4) the average paler, smaller and more diffuse dark spots on the gaster. The female, which also seems to be distinct, differs from the female of typical *curvispinosus* in (1) the very short epinotal spines which are shorter than broad at the base; (2)

the somewhat less robust thorax; (3) the paler and less extensive infuscation, particularly on the gaster. In view of the variability of *curvispinosus*, we hesitate to describe this tree-living formula as a distinct variety until we have been able to examine much more material.

Winged phases were taken in early July.

Leptothorax ambiguus Emery—This species seems to be typically a meadow ant. We have found it in nearly every growth of beard grass that we have examined, less often in more thickly vegetated fields. Several colonies were found in a moist sunny pasture in the bottom of a gulch. The colonies usually nest in hollow dead stems at the base of grass tufts, although one colony from the low pasture was nesting in the soil. Males were taken in the nest in early July.

Our specimens were identified by Dr. M. R. Smith who compared them with specimens in the Pergande collection in the U. S. National Museum. The Pergande specimens are from Hill City, South Dakota, and are believed to be cotypes. Since Emery's original description is inadequate for the determination of *L. ambiguus*, we add the following separation of this form from *L. curvispinosus*.

Worker.—Differs from the worker of *L. curvispinosus* in the following characters: 1) The epinotal spines are shorter, from $\frac{1}{2}$ to $\frac{2}{3}$ the length in *L. curvispinosus*, as far apart at the base as they are long, slightly diverging, obtusely pointed. 2) The petiole is proportionately shorter and the node higher than in *L. curvispinosus*, only slightly compressed laterally above when seen from behind, the anterior slope concave and steep, the posterior slope sharply convex or angulate. 3) The postpetiole in profile is larger in proportion to the petiole, and is subquadrate; from above, the postpetiole is rectangular, $1\frac{1}{4}$ times as broad as long. 4) The sculpture on the thorax is more opaque than in *L. curvispinosus* and more uniform; the rugae are more irregular and the interrugal spaces coarsely and densely recticulate-punctate. 5) The color is uniformly tawny yellow, the spots on the sides of the gaster is *L. curvispinosus* being absent in *ambiguus*.

Female.—Differs from the female of *L. curvispinosus* as follows: 1) The epinotal spines are obtuse, as broad as long at the base. 2) Petiole and postpetiole as in the worker, and differing from the *curvispinosus* female in the same manner as do the workers of the two forms. 4) The sculpture is less shining.

Male.—Differs as follows from the male of *L. curvispinosus*. 1) Smaller size (2.2-2.4 mm). 2) The epinotum lacks spines, bearing instead small, low, broadly rounded tuberosities. 3) Front and vertex are rather delicately reticulate-rugose, without the more prominent longitudinal rugae of *L. curvispinosus*. 4) Color is lighter than in *L. curvispinosus*, very pale yellow, gaster and head slightly darker.

Leptothorax ambiguus pinetorum var. nov.

Description.—Worker: differs from ambiguus in the length of the epinotal spines and in the sculpture. The epinotal spines are longer in proportion to the thorax than in our specimens of *ambiguus*, the length of the spine divided

by the length from the declivity of the pronotum to the base of the spine being .33 to .24 in *pinetorum*, while the corresponding ratio in *ambiguus* is .24 to .15. The coarse longitudinal rugae on the thorax are less conspicuous in *pinetorum*.

Female: Differs from the female of ambiguus in smaller size and in the length of the epinotal spines. The length is 2.5-2.9 in *pinetorum*, 3.2-4.2 mm. in *ambiguus*. The epinotal spines are rather slender, twice as long as broad at the base; they are about as long as broad in *ambiguus*. The *pinetorum* females also average slightly darker than *ambiguus*.

Male: Differs from the male of *ambiguus* in smaller size, 1.95-2.2 mm. (length of *ambiguus* male ,2.2-2.4 mm.), and in the fewer erect hairs on the surface of the body.

Described from a colony comprising 12 wokers, 1 dealate female, 2 alate females and 5 males, taken July 10, -938, Jackson County. The colony was nesting in a small, hollow, dead root covered by pine needles on the edge of a dry piney bluff.

Four colonies and several stray workers of this form have been taken in or near the type locality. All have been small, comprising 10 to 25 workers. Besides the type colony, one nest consisted of a small hollow twig, another of a curled-up dead leaf, both just under the pine needles. The fourth colony was nesting in the bark of a pine log.

Leptothorax texanus Wheeler—Several colonies of this species were found nesting in sandy soil under pine needles on the edge of dry, open sandstone bluffs in Jackson County. The workers ran about very rapidly in the sun over the pine needles. Winged phases were taken from a nest in early July.

Leptothorax (Dichothorax) pergandei Emery—Seen everywhere in dry, sunny fields and meadows, sometimes in dry open woods. Winged phases were taken from nests in early July.

Harpagoxenus americanus (Emery)—Found throughout the area occurring approximately in a ratio of 1 colony to every 15 of its host, *Leptothorax curvispinosus*. The habits of this slavemaker are described in a separate paper.[6]

Tetramorium caespitum Linneus—A few colonies of this ant were found in alleyways and along sidewalks near the business district of Jackson.

Strumigenys (Cephaloxys) pergandei Emery—Our notes on species of this genus are presented in a separate paper.[2]

Strumigenys (Cephaloxys) rostrata Emery
Strumigenys (Cephaloxys) abdita Wesson and Wesson
Strumigenys (Cephaloxys) manni Wesson and Wesson
Strumigenys (Cephaloxys) venatrix Wesson and Wesson
Strumigenys (Cephaloxys) pulchella Emery
Strumigenys (Cephaloxys) missouriensis M. R. Smith
Strumigenys (Cephaloxys) reflexa Wesson and Wesson

6 Wesson, L. G., Jr., Contribution to the Natural History of *Harpagoxenus americanus* Emery. Trans. Amer. Ent. Soc. **65**:97-122. 1939.

Strumigenys (Cephaloxys) deitrichi M. R. Smith
Strumigenys (Cephaloxys) ornata Mayr
Strumigenys (Cephaloxys) bimarginata Wesson and Wesson
Strumigenys (Cephaloxys) clypeata Roger
Strumigenys (Cephaloxys) medialis Wesson and Wesson.

Trachymyrmex septentrionalis (McCook)—Taken occasionally in the southern and western portions of the area. Colonies have usually been found on dry, shaly clay hillsides in open woods, often under stones. Workers were found a few times in scattered woods on limestone soil. Numerous colonies of this species were found on a sandy elevation in southern Adams County, described under *Pheidole vinelandica,* where they were nesting in the sand in partial shade; and again on the sandy loam slides, bearing scattered pitchpines, beardgrass and huckleberry at the base of a sandstone bluff in Jackson County. Winged phases were taken from a nest in late August.

Dolichoderinae

Dolichoderus (Hypoclinea) taschenbergi var. *gagates* Wheeler—We have found this species occasionally along the edge of woods or in dry, brushy fields where it usually seems to be associated with the sandy soil on which pine is the predominating tree. The nests found were similar to those described by Wheeler[7] from the New Jersey pine barrens, consisting of irregular funnels filled with vegetable detritus, often in and under a clump of grass.

Dolichoderus (H.) plagiatus Mayr—Found widely but not abundantly throughout the region in open woods where the workers forage over the foliage of low bushes and herbs. The nests found have consisted of a curled-over dead leaf or a hollow weed stem, the gaps sealed with carton. Some specimens found in Scioto County verge toward the variety *inornatus* in having the gaster entirely black except for a dull reddish spot at the base of the first gastric segment. Males were found in the nest in the middle of August.

Dolichoderus (H.) plagiatus pustulatus beutenmuelleri Wheeler—This ant is found rather commonly running over the grass and low bushes of dry, upland meadows. Some of the nests found are of special interest as they are made largely of carton. Built around the dead and living stalks at the base of a clump of grass, they are irregular, oval or oblong carton chambers about an inch in length. The chamber rests on the ground which is scooped out into a shallow basin. No galleries enter the soil. The entrance is a small tube, wide enough to admit a single ant, projecting 6-18 mm. out from the side of the nest, somewhat like the spout on a teakettle. The chamber may be partially divided into two or more compartments depending on the number and arrangement of the intersecting grass stalks. The carton is hard and firm, thinner and made of smaller particles than that of *Crematogaster lineolata.* Other colonies have been found nesting merely in an opening among dead pine needles on the ground or in the detritus at the base of a clump of grass. Winged forms are found in the nest in late August.

[7] Wheeler, W. M., An Annotated List of the Ants of New Jersey. Bull. Amer. Mus. Nat. Hist. **21**:371-403. 1905.

Tapinoma sessile (Say)—This species nests in about every available, but preferably dry situation throughout the area. Our specimens vary from pale, small (1.5 mm.) forms with shallow mesoepinotal constriction to large (3.2 mm.), dark forms with deep mesoepinotal constriction. At the same time, individuals from a given colony are rather uniform. The variation can scarcely be due to environmental influence, since on one occasion colonies of both the largest and the smallest forms were taken from similar nesting sites within 3 feet of each other.

Iridomyrmex analis (André)—Numerous colonies of this ant were found on a dry hilltop in Adams County on which the limestone and clay soil is sparsely covered by beard grass and cedars. We have not been able to find it in similar, intensively examined places in the eastern portion of the area.

Camponotinae

Brachymyrmex heeri depilis Emery—A versatile ant in habitat, it seems to be most abundant in open woods, but we have also taken it in rotten logs in dense moist woods, and in meadows and dry fields.

Prenolepis imparis (Say)—This ant is predominantly nocturnal but is often seen through the day during cool or cloudy weather or in damp shaded situations. The colonies are abundant in all types of woods. Workers from different colonies vary in color from tawny to nearly black. We have never taken this species under stones or logs.

Paratrechina (Nylanderia) parvula Mayr—Common nearly everywhere except in very cool, moist woods. Our material shows considerable variation which we have been unable to refer to any but this species on comparison with material in the Wheeler collection at the Museum of Comparative Zoology, Harvard University. Specimens from wooded places are usually dark brown or black and have few or no hairs on the antennal scapes. They agree with typical *parvula*. Specimens from dry or exposed situations, on the other hand, are usually paler and have a variable number of hairs on the antennal scapes. These latter may prove to be a distinct form, but in the absence of males we cannot decide. Nevertheless, we have occasionally found colonies in which some of the workers bore a variable number of hairs on the antennal scapes while others bore none, suggesting that this character may not be entirely reliable.

Lasius niger var. *neoniger* Emery—*Lasius niger* var. *americanus* Emery.—Common nearly everywhere. Specimens bearing erect hairs on the antennal scapes, referable to *neoniger*, are much less abundant than *americanus*, but are found over the same range of habitat.

Lasius brevicornis Emery—Found occasionally in dry woods, usually under stones. Workers from one colony have the antennal scapes longer than usual, reaching nearly to the posterior border of the head.

Lasius flavus nearcticus Wheeler—A moderately abundant species found under stones and logs in upland woods.

Lasius (Chthonolasius) umbratus mixtus aphidicola Walsh—Common in practically all kinds of woods, and especially in open ones. Often found nesting in and under logs and stumps as well as in the soil.

Lasius (Acanthomyops) interjectus Mayr—Galleries are occasionally found under stones on the edge of or in scattered woods.

Formica sanguinea rubicunda Emery—Occurs occasionally in open woods with its slave, *Formica subsericea.* During a raid of these ants in mid July, a great number of small braconid wasps (*Elasmosoma* n. sp.) was seen hovering above the *rubicunda* army as it attacked a *subsericea* nest. The wasp continually sought to mount the gasters of the ants, particularly the *rubicunda,* and those that were successful thrust the tips of their abdomens to the ventral surface of the ants' gasters. The ants attacked hem fiercely. We were unable to find eggs deposited on the surface of the ants.

Formica sanguinea subintegra Emery—More abundant than the preceding form and usually found in more open and drier woods.

Formica sanguinea subintegra gilvescens Wheeler—A single colony referable to this form was found in an open pine grove in Hocking County in mid August in the act of raiding a small nest of *Formica subsericea.* Although the colony comprised (perhaps) 200 or 300 *gilvescens,* the raid was much more disorganized than that of the typical *subintegra.* The workers were compared with type specimens of *gilvescens* and agree with these in all characters except color. Here they approach typical *subintegra* but closely resemble specimens taken by Wheeler in Wisconsin which he referred to *gilvescens.*

Formica truncicola obscuriventris Mayr—A number of workers belonging to this form were taken in a small clearing in moist, deep woods in Scioto County.

Formica truncicola integra Nylander— Found occasionally in the southern and western portions of the collecting area. Colonies nest in and under logs and stumps in fields and open, well drained woods.

Formica difficilis Emery—Found occasionally in dry, bushy fields under stones and logs which it banks with vegetable debris. A migratory female was taken in mid July.

Formica microgyna rasilis Wheeler—Common in very open, dry woods and in upland fields, especially where there are scattered bushes and small trees. Isolated workers are extremely difficult to follow since their established trails invariably lie under leaves and grass on the ground. Migratory females have been taken in early July. A single female was found in a nest of *Formica subsericea,* suggesting that this species is the temporary host of *rasilis.* Males, females and workers agree well with type material of *rasilis* in the Wheeler collection, and also with paratype specimens of *F. querquetulana* Kennedy and Dennis.

Formica exsectoides Ford—The characteristic dome-shaped mounds of this

species are found occasionally on dry, grassy or bushy hillsides. None of the mounds that we have seen have been more than 50 cm. high and 1 m. in diameter.

Formica pallidefulva Latreille.—*Formica pallidefulva schaufussi* Mayr—*Formica pallidefulva schaufussi incerta* Emery—Very common; the small colonies nest in open, sunny spots including lowland pastures, clearings in the woods and the driest and most barren upland fields. They are much more abundant in the drier situations.

Our specimens are exceedingly variable in size, color and pilosity. An examination of the material shows 3 terminal forms in the group: 1) pale, reddish-yellow forms with no hairs on the gula, thoracic dorsum or petiole, and usually smaller in size; 2) pale, reddish-yellow, usually larger forms, with numerous hairs on gula, thoracic dorsum and petiole; 3) darker forms with brownish head, dark-brown gaster and yellowish-red thorax, scattered hairs on thoracic dorsum and few or none on gula and petiole, variable in size. Between these three are all intergradations. Form no. 1 verges on the typical *pallidefulva,* but the yellowish-red females usually show faint darker spots on the mesonotum; form no. 2 is essentially typical *schaufussi;* form no. 3 is var. *incerta,* transitional to *F. nitidiventris* from which it differs in paler color, less shining surface, greater pubescence, and the uniform darker color of the males. The petiole is quite variable in size and shape in all our forms.

Formica pallidefulva nitidiventris Emery—*Formica pallidefulva nitidiventris fuscata* Emery—Common; found in the same situations as *schaufussi,* but more abundant than that form on moister hillsides and in open woods. Our material varies from specimens with reddish thorax and darker head and gaster and numerous hairs on the thoracic dorsum *(nitidiventris)* to nearly black specimens with few or no hairs on the upper surface of the thorax (var. *fuscata*). Occasionally the petiole bears 1 or 2 erect hairs.

Formica fusca subsericea (Say)—Found abundantly in and on the edge of woods and among scattered trees; especially common on dry, open, wooded hillsides. Workers from small colonies often show transitions to typical *fusca* in the more dilute pubescence.

Formica neogagates Emery—A single small colony of this species was found in open, upland oak woods in Pike County.

Polyergus lucidus Mayr—Found occasionally in sunny places or open woods nesting with its slaves, which have comprised principally *Formica nitidiventris.* A raid was witnessed in late July at 5:00 P. M. The army, about 150 strong, in a solid body not longer than 50 cm., marched straight to a colony of *Formica nitidiventris.* There were no stragglers and the ants hesitated only once. The *Polyergus* disappeared under some leaves which hid the *Formica* colony, and in a few seconds began reappearing carrying pupae and chasing the frightened *Formica* workers which were emerging from the nest with their brood. There was little, if any fighting. The *Polyergus* did not begin their return until almost all of their number were on the surface with pupae. Then,

as though at a signal, the army started for home nearly as compactly as it had come. Winged females were observed leaving a colony on August 5.

Camponotus castaneus (Latreille)—Taken occasionally in open, dry, upland oak woods. On very rocky, barren or washed soil it is commoner than *C. americanus*. Galleries are often found under stones.

Camponotus castaneus americanus Mayr—Usually more abundant than the preceding form, it nests in the ground in open, well-drained woods. The workers forage on surrounding trees and bushes.

Camponotus herculeanus pennsylvanicus (Degeer)—Found commonly nesting in dead branches or cavities of trees, rarely in dry logs or stumps.

Camponotus herculeanus pennsylvanicus ferrugineus (Fabricius)— Found often in woods where it nests in and under rotten logs and stumps.

Camponotus herculeanus ligniperdus noveboracensis (Fitch)—A major worker of this form was received from Mr. E. S. Thomas, Columbus, Ohio, having been collected by Dr. J. S. Hine in Columbus, 75 miles north of Jackson.

Camponotus caryae Emery—Workers of this species have been seen running on the trunks of nearly every large oak or hickory examined, less often on the trunks of other trees. The nests are cavities in the bark or dead branches, sometimes in the bark of logs lying on the ground.

Camponotus caryae var. *pardus* Wheeler—A single female was taken from a cavity in a stick on the edge of some woods. A colony was found in a hollow weed stem in a thicket along a woodland road. Our specimens have the paler areas of the body darker and less extensive than the typical form from New Jersey, possibly verging toward var. *minutus* Emery.

Camponotus caryae subbarbatus Emery—Found abundantly in and along the edge of woods. The nests are located in cavities in hollow sticks and stems on the ground. The workers forage over low vegetation.

Camponotus caryae discolor Emery—A single colony was taken from an insect gallery in a living branch of a red oak in a field, Gallia County. The head of the majority of the workers is infuscated, especially in the majors, least in the minors, possibly indicating a transition toward *cnemidatus*.

Camponotus caryae discolor cnemidatus Emery—Found on several occasions on large oak trees nesting in cavities in the bark.

JACKSON, OHIO.

The Presidential Range of New Hampshire as a Biological Environment, with Particular Reference to the Insects

Charles P. Alexander

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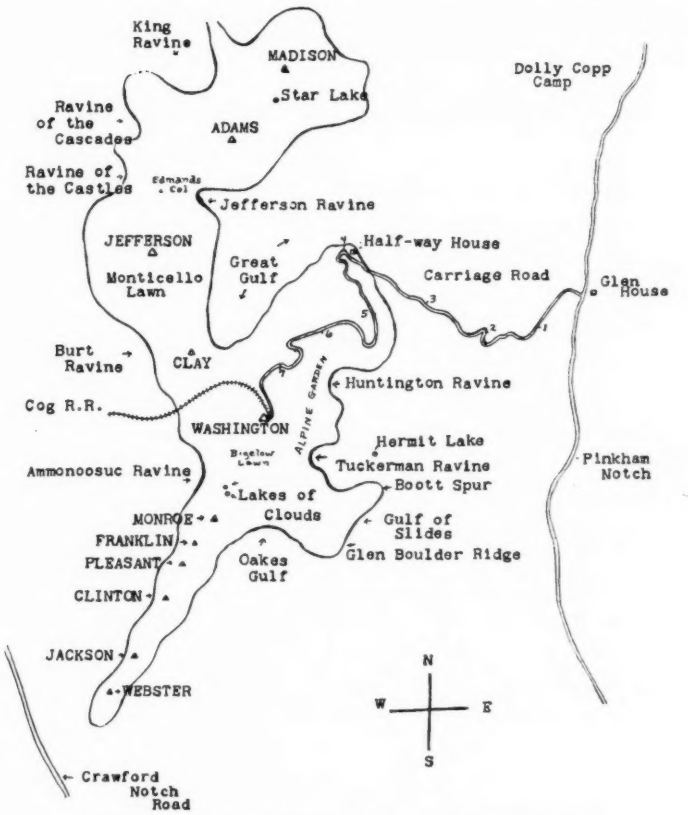
1. Introduction

From the viewpoint of scientific interest, the Presidential Range of the White Mountains, in northern New Hampshire, has been termed a *"locus classicus"* by Pease (1924). The period of scientific activity on the range, particularly of the botanists, has extended over more than a century and a half. Certainly there is no other mountainous area in the United States that has been under such close scientific scrutiny for so long a period. Nevertheless, insofar as the insect fauna is concerned, a vast amount of work remains to be done, since the collected specimens and data are so scattered and disconnected that merely a start has been made toward the preparation of a detailed record. When the published accounts of insects are compared with the detailed list of species known from the somewhat comparable area of Mount Desert island, Maine (Procter, 1938) or with the record of the higher plants of the Presidentials (Pease, 1924), the comparison becomes highly significant and indicates clearly the extent of the problem confronting the entomologists.

Later in this paper, a chronological record of the more important entomological activity, particularly of the Nineteenth Century, has been presented. As has been the case with the botanists, the entomologists find that the great center of interest in the range is the summit, where unusually rigorous to virtually arctic conditions obtain. The summit of Mount Washington, highest of the Presidentials, has been called an "Arctic island in the temperate zone," encircled by the isothermal line of 26° Fahrenheit. Although at a latitude of 44° 15′ North, it has virtually the same climate as has northern Labrador at 60°, or more than 1,000 miles to the northeastward. Hitchcock (Mount Washington in Winter, 1871:32) further indicates that the climate corresponds well with that of western Greenland at about 70° North Latitude. With such climatic conditions obtaining it would appear certain that many



SKETCH MAP OF THE PRESIDENTIAL RANGE, NEW HAMPSHIRE

Area within the continuous line indicates the limits of the Arctic-Alpine and upper Hudsonian zones.

Names of mountains in large Capitals; Alpine Garden in small capitals; other features, as glacial cirques (Ravines and Gulfs) and other landmarks in small letters. Figures at intervals along Carriage Road between Glen House and summit of Mount Washington indicate position of mile-posts.

Altitudes of Mountains

Madison	5380 feet	Monroe	5390 feet
Adams	5805	Franklin	5028
Jefferson	5725	Pleasant	4775
Clay	5534	Clinton	4275
Washington	6288	Jackson	4012
		Webster	3876

interesting problems concerning the local distribution of plants and insects would be found, and such is indeed the case.

In the present report I have attempted to indicate briefly the factors that combine to produce this inhospitable environment in New England, and to give a brief account of the flowering plants and certain of the insects, particularly those of the higher altitudes. As later indicated, it is to be hoped that more concerted action toward the preparation of a detailed list of the insects of the area may be evoked.

The Presidential Range lies almost entirely in Coös county, New Hampshire, and is part of the White Mountain National Forest Area. Easiest access to the highest summits by foot are via the Tuckerman Ravine on the east and the Crawford and Ammonoosuc Ravine trails on the west. There is an eight-mile automobile road extending from the Glen House in Pinkham Notch to the summit of Washington, while the famous Cog Railway, on the west side, extends from the Base Station to the summit. Excellent accommodations for visitors are provided at the Summit House on Washington and at the two Appalachian Club Huts, one at the Lakes of the Clouds, the second at the northern end of the range near Madison Springs. My personal acquaintance with the Presidentials began in 1932 since which date almost annual trips to the summit have been made. These trips have always been taken with Mrs. Alexander and with Mr. Walter H. Harrison and Mrs. Harrison, of Amherst, Massachusetts. Mr. Harrison's extensive knowledge of the mountain, particularly of the geology and the flora, has been particularly helpful. During August 1938, my brother, Professor William P. Alexander, of Buffalo, N. Y., with his wife, camped with us and we spent two days and nights on the summits. During this period many of the most interesting environments have been examined, with base camps in Pinkham and Crawford notches, and including many traverses of the summits via Tuckerman, Huntington, Ammonoosuc and King Ravines. A preliminary record of the Tipulidae of the area, with an annotated list of the localities visited, has been published (Alexander, 1936b).

2. Physical Features; Glaciation

As well-described by Antevs (1932), the Presidential or Mount Washington range consists essentially of a narrow ridge, extending for about fourteen miles in a north-south direction. Including its minor northern and southern peaks, between the villages of Gorham on the north and Bartlett on the south, the range measures some twenty-two miles in length. This narrow ridge is deeply dissected by many bowl-shaped basins and deep, round-bottomed valleys having semicircular, precipitous headwalls. Beginning on the north and passing southward, the peaks (altitudes in feet) are as follows: Pine (2440); Madison (5380); the Adams group, with John Quincy Adams (5470), Adams (5805) and Sam Adams (5585); Jefferson (5725); the three peaks of Clay, the highest (5534); Washington, whose latest corrected altitude is 6288.066 feet (Shaw, 1939:2, 3), exceeding any other mountain in northeastern North America. Southwestward from Washington lie Monroe (5390);

Franklin (5028); Pleasant (4775); Clinton (4275); Jackson (4012); and Webster (3876). The chief basins or cirques that dissect the range on the east are the Madison Gulf, Jefferson Ravine, Great Gulf, Huntington Ravine, Tuckerman Ravine, and the Gulf of Slides; on the south, Oakes Gulf; on the north and west are the King Ravine, Ravine of the Cascades, Ravine of the Castles, Burt Ravine, and Ammonoosuc Ravine. The hydrography of the range shows that the drainage involves three major river systems, — the Connecticut, the Androscoggin, and the Saco. The range is cut off from the Carter Range to the east by the Pinkham Notch; from the mountains to the west, especially by the Crawford Notch.

The Presidentials are composed primarily of metamorphic rocks of sedimentary origin. The highest peaks are underlaid by alternating layers of quartzite and schists that date from the lower Devonian (330 millions of years). South of Washington occurs a narrow calcareous bed, or *granulites*, most accessible some 500 feet south of the Lakes of the Clouds Huts. These granulites date from the middle Silurian (340 millions), and their outcroppings support the lime-seeking flora of the range. A still older formation, probably Ordovician, found on Mounts Franklin, Monroe and Clay, has been called by geologists *injection gneiss* (Billings, 1938). The oldest rocks in the range, probably Ordovician (370 millions) are of volcanic origin, occurring as a wide belt on the lower slopes of the northern peaks. The only granites in the range are relatively small and unimportant bodies, though large areas are to be found outside the range limits to the north and northwest. The soils derived from the disintegration of this so-called Montalban group constituting the highest summits are necessarily poor and meager, since the minerals comprising the schists and quartzites are nearly indestructible (Crosby, in Pease, 1924:62). Furthermore, much of the accumulated weathered soil of ancient times must have been removed by the action of the Wisconsin ice-sheet. The effects of frost action on weathering and the local movements of debris in the Presidentials have been detailed by Antevs (1932:34-70).

Glaciation.—As early as 1875, Professor C. H. Hitchcock found definite evidences of glaciation on the summit of Washington, this being shown by the presence of foreign boulders and other débris (chiefly granites, quartzites and slates) from the more northern and northwestern ledges. These erratics have been found to within twenty feet of the highest point of Washington. Other evidences of Pleistocene glacial action at and near the summit, such as glacial striae, sheepbacks, perched boulders, and rocking stones, have been discussed in detail by J. W. Goldthwait (1913 a, b) and by Antevs (1932: 1-7). Still more recent proof that the great ice sheet reached this very highest point has been provided by Mr. R. P. Goldthwait (Mount Washington Observatory News Bull. 1:4; 1937). While excavating at the summit there was discovered a pocket of glacial till above the bed rock of mica schist, containing, in addition to local material, small pieces of fine-grained gabbro absolutely foreign to the range. Such must have been transported southward and upward from mountains northwest of the Presidentials. Such proofs indicate that the ice in this region was at least 5,000 feet in thickness. The dissecting ravines

and gulfs of the range are glacial cirques and troughs hollowed out by local alpine glaciers. These troughs presumably were formed during various glacial epochs prior to the Wisconsin or last ice-sheet, which completed the removal of the masses of débris quarried by these valley glaciers.

The effect of the glacier on pre-existing life on the range must have been catastrophic. The plant and animal life was destroyed or forced ahead of the glacier to find sanctuary in the southern Appalachians. The present flora and fauna must have reestablished themselves on the range only following the northward retreat of the ice, some 20,000 to 25,000 years ago. Many such forms presumably followed the sheet northward as it melted away and became isolated as relicts when the ice passed onward. This is the case well-exemplified by the White Mountain Butterfly, the range's most famous single insect species. As expressed by Grote, what presumably transpired was about as follows: "Return became at length impossible. They advanced behind the deceiving local glaciers step by step, up the mountain side, pushed up from below by the warm climate, which to them was uncongenial, until they reached the mountain peak, now bare of snow in the short summer." Further retreat of the ice sheet left these arctic relict plants and animals stranded on the highest parts of the range where they have persisted to the present day.

From a comparison of the isotheral and isocheimal lines of Mount Washington and the European Alps, Scudder (1874:342) has estimated that if the summit of Washington was somewhat less than two thousand feet higher than it is (or approximately 8,000 feet), it would reach the upper limits of the alpine district, or the region of perpetual snow. It has been stated further that a lowering of the mean annual temperature by only 6° Fahrenheit would cause a return of the Ice Age. As it is, there is no permanent snow on the Presidentials, the nearest approach being the snow field and arch in Tuckerman Ravine and in boulder caves near the foot of the headwall of King Ravine where ice is found throughout the year.

3. Climate and Meteorology

It is fortunate that relatively complete and detailed climatological records for the summit of Washington are available. A private enterprise, the Hitchcock-Huntington expedition, spent the winter of 1870-71 on the summit, beginning operations on November 13, 1870 (Hitchcock, Mount Washington in Winter, 1871). Following this, the United States Signal Service made detailed observations for the succeeding seventeen years (1871-1887) and for summers only for five additional years, or until 1892. There was then a break in the records until the Fall of 1932 when the Mount Washington Observatory began operations with a finely equipped building, well-trained staff, and the most modern meteorological instruments. These latter records are available in the Mount Washington Observatory News Bulletin, November 1937 - date: Gorham, N. H.

The climate of Mount Washington is notorious. It has been described succinctly in three words, — *fickle, fierce, forbidding*. As an introduction to

a brief discussion of the climate and meteorological conditions obtaining on the mountain, the following account by Pagliuca (1937) is given:

There are several reasons why the Mt. Washington weather is abnormally severe. The mountain is located in a region of frequent storms. Disturbances advancing eastward from the Great Lakes region or northward from the Gulf of Mexico roughly converge over northern New England. Mt. Washington is near enough the coast to be frequently affected by the fast moving, often very severe, coastal storms, and it is near enough to the Newfoundland region to feel the effect of those quasi-stationary storms which are very active there. The duration and severity of storms are intensified by altitude and barrier effects originating from the particular height of Mt. Washingon (6,284 feet) and from its location at the center of a mountain range stretching approximately north-south, and therefore offering a natural barrier to the prevailing westerly winds.

At the level of Mt. Washington, condensation is very frequent, thus low clouds are forced over the summit, or cloud caps will envelop it as a result of moisture, not previously in a cloud form, being cooled and condensed in the forced ascent over the upper slopes. Consequently, fog is very frequently experienced at the summit. During the year 1933 fog was recorded 318 days, or 87 percent of all days, and on 4,600 hours, or 52.5 percent of all hours. Precipitation is likewise increased by the mechanical lifting of bodies of moist air, and by the added contribution from fog-water and rime. Considerable experimenting on improved precipitation gages at the summit indicates definitely that ordinary gages will give deficient catch, unless equipped with devices tending to shield the upper rim of the gages from the wind.

The warm, moist air preceding the center of a moving cyclone makes its influence felt first at higher levels. This combined with an as yet unexplained phenomenon of active pressure fall long after the arrival of the cold air at the summit following the passage of the central part of the storm, has the tendency to increase the amplitude (duration) of a storm cycle. Thus the time between storm activities at the summit is much shorter than at the nearby lowland. The barrier effect consists of a general lowering of the summit temperature with respect to the temperature of the free air at the same level, and a considerable increase of the wind velocity at the summit. Although from a temperature standpoint the climate on the summit is low Arctic, its proverbial rigor is due to the frequent combination of very low temperatures occurring with winds of super-hurricane force. The resulting 'cooling effect' is hardly comparable with that at any other place where the climate has been observed. One of the fiercest cases was experienced the morning of January 29, 1934, when the lowest temperature of 46.5° Fahrenheit below zero occurred with a wind of 100 miles per hour.

Temperature.—The temperature means and extremes throughout the year are summarized in the table below. As a basis for comparison, the mean annual temperatures for Hebron, Labrador, and for Berlin, New Hampshire, are given. It may be noted that the lowest temperature ever recorded was 59° Fahrenheit below zero in February 1871; the highest 72° above zero in July 1881. A composite of minimum temperatures in the period 1932-1938 shows that freezing temperatures occurred in every summer month of one year or another.

Summer temperatures. The following July temperatures for the years 1870 to 1892 are summarized:

Absolute Maximum: Average 64°; highest 72° (1881).
Absolute Minimum: Average 30°; lowest 24° (1888).
Maximum daily range; Average 20°; from 17° (1892) to 24° (1888).
Number of days with frost; maximum 3 days (1882).

All temperatures given below are in Fahrenheit degrees.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Absolute Minimum (1870-71)	-45	-59	-4	4.0	15.0							
Absolute Minimum (1932-39)	-46.5 (1934)	-40 (1934)	-26.0 (1934)	-2.0 (1939)	0.3 (1936)	21.0 (1936)	30.0 (1936)	26.5 (1934)	14.0 (1936)	-2.0 (1936)	-19.2 (1936)	-46.2 (1933)
Absolute Maximum (1932-39)	40.0 (1937)	42.0 (1937)	45.0 (1938)	53.0 (1938)	63.0 (1937)	71.0 (1933)	69.0 (1939)	70.0 (1935)	64.0 (1939)	59.0 (1938)	50.0 ('35-'38)	45.0 (1934)
Maximum Mean (1870-92)	18.2 (1880)	14.1 (1884)	18.0 (1871)	30.0 (1878)	42.2 (1887)	49.0 (1884)	51.3 (1887)	50.7 (1872)	48.6 (1881)	35.4 (1879)	21.5 (1876)	16.6 (1881)
Maximum Mean (1932-38)	13.1 (1937)	10.4 (1937)	21.6 (1936)	25.4 (1933)	38.3 (1937)	46.1 (1933)	51.4 (1937)	53.8 (1937)	46.3 (1934)	30.1 (1935)	26.5 (1935)	15.1 (1936)
Minimum Mean (1870-92)	-2.0 (1875)	-2.5 (1875)	-1.3 (1872)	14.2 (1874)	26.4 (1871)	38.8 (1881)	44.6 (1884)	43.6 (1885)	35.6 (1875)	23.9 (1876)	8.6 (1873)	0.6 (1876)
Minimum Mean (1932-38)	1.6 (1935)	0.0 (1936)	5.8 (1937)	19.7 (1936)	27.2 (1935)	44.8 (1935)	49.0 (1934)	43.1 (1934)	36.2 (1935)	27.0 (1934)	12.2 (1933)	2.6 (1934)
Av. Annual Mean (1932-38)	7.6	5.5	11.8	22.5	35.4	45.5	49.3	48.3	41.5	28.9	19.9	8.4
Av. Annual Mean (1870-92)	5.5	6.7	9.2	21.2	35.3	44.1	47.8	46.5	40.3	30.2	17.8	9.9
Hebron, Labrador* (Av. Ann. Mean)	6.0	5.5	5.1	18.9	31.6	36.8	44.6	46.9	41.3	32.0	23.1	6.0
Berlin, N. H.** (Av. Ann. Mean)	16.8	17.9	35.7	46.8	54.7	60.8	72.4	63.0	59.0	46.4	29.4	16.4

* Hebron, Labrador (Pease, 1924:70) taken from Coleman, 1921, representing averages for 7 years (1905-1911). Mean for year 27.9°.

** Berlin, New Hampshire (At foot of Presidential Range, to show comparison with summit); for year 1921 only; Mean for year 43.3°. Mean for year for Washington Summit 26.1°.

Temperature increases due to altitude. The average decrease in temperature with altitude on Mount Washington equals 1° Fahrenheit for every 328 feet of ascent, or approximately 3° per 1000 feet of climb. For West Virginia, Hopkins (1938:91) gives a slightly lower figure, 1.1° Fahrenheit for each 400 feet of altitude or 2.75° per 1000 feet.

Precipitation.—The table given below indicates the inches of rain at the summit of Washington. The average annual rainfall, between 80 and 82 inches, is approximately twice that of the surrounding lowlands (averaging about 40 inches).

Precipitation in inches; Mount Washington Observatory 1932-39

	Jan.	Feb.	March	April	May	June
Maximum	10.55 (1935)	10.45 (1937)	15.57 (1936)	10.03 (1934)	9.38 (1937)	8.18 (1937)
Minimum	4.59 (1933)	4.05 (1934)	4.38 (1934)	4.91 (1938)	2.26 (1934)	4.25 (1934)
Means	7.81	6.08	9.18	8.46	5.48	5.77

	July	August	Sept.	Oct.	Nov.	Dec.
Maximum	8.30 (1938)	9.12 (1938)	14.07 (1938)	11.58 (1937)	9.37 (1934)	10.56 (1936)
Minimum	3.94 (1933)	3.80 (1939)	3.56 (1933)	2.23 (1935)	4.70 (1936)	3.69 (1935)
Means	5.17	6.08	6.19	6.78	6.52	7.40

Maximum total for single year	105.36	(1937)
Minimum total for single year	68.72	(1933)
Average total per year, 1932-37	80.92	
1872-90 Average precipitation for year	82.21	
(Winter 32.13; Spring 15.25; Summer 18.96; Autumn 15.87)		
Minimum total for single year	56.51	(1872)
Maximum total for single year	121.13	(1881)

In measuring snowfall, it should be borne in mind that one inch of rain is equivalent to about ten inches of average snow. The fall of snow at the Tuckerman shelter, at the lower end of Tuckerman Ravine, altitude about 3,700 feet, reached a maximum depth of 146 inches, or more than twelve feet, during the winter of 1938-39, according to Arthur E. Bent. The prevailing westerly and northwesterly winds blow the snow from the summits and higher altitudes into the lee-side ravines, notably Tuckerman. Here the drifts accumulate throughout the winter and spring, persisting into the summer as a miniature glacier and finally as a snow arch until mid-July or even later. Skiing on this snow mass continues well into July.

Ground frost. Excavations at the Madison Springs Huts (altitude 4,825 feet) in late July 1928 showed the black soil to be frozen at a depth of two feet and continued frozen to a depth of more than four feet. During mid-August 1928, at the Lakes of the Clouds Huts (altitude 5,000 feet) the earth was found frozen at a depth of three feet and continued frozen to more than six feet. This indicates that permanent ground frost persists throughout the year in suitable places (J. B. Dodge, in Antevs, 1932).

Compared with the lowlands, the much greater frequency and longer duration of cloudiness on the higher peaks of the White Mountains is notorious. Dawson, in 1862, wrote: "When the summer mists roll around the summit of Mount Washington, it is in every respect the precise counterpart of an islet anywhere on the coast of America from Cape Breton to the Arctic seas."

Wind.—Perhaps the most striking meteorological element on Mount Washington is the wind, or, as well expressed by Bent (1939:9): "It is in the wind that the mountain becomes truly magnificent."

The yearly average wind velocity is about 40 miles per hour. Great wind velocities are usually limited to winter and to periods when there are clouds upon the mountains, and may occur when there is complete calm at the base. Huntington cites a case where the wind registered 96 miles per hour at the summit, while 2677 feet below, at the Base Station, there was not enough wind to move the anemometer. The period from October 1, 1938 through March 1939 may be cited as an example. This period includes 182 days, on 111 of which the wind exceeded hurricane speed (75 miles per hour). In Januaty 1939, the wind exceeded hurricane force on 25 days. The maximum wind of this period was 144 miles from the northwest on January 3, 1939 and again from the southwest on February 20, 1939. During the four-month period from December 1938 through March 1939, the *average* wind velocity was 59.7 miles per hour.

The single greatest blow was during the gale of April 12, 1934, when the anemometer read 231 miles per hour. According to Bent (1939) this is the highest natural wind velocity ever officially recorded by means of an anemometer anywhere in the World. The famous New England hurricane of September 21, 1938, reached Mount Washington and here attained a velocity of 163 miles per hour. This hurricane was preceded by heavy precipitation that soaked the soil, and the wind sweeping over the shoulders of the mountain appears to have started landslides where trees were uprooted near the top of the steep slope near the head of the Ammonoosuc Ravine. A comparison of these two great wind storms is of interest. The 1938 hurricane, while attaining less velocity, was more gusty and of shorter duration, averaging over 100 miles per hour for only four hours. The 1934 storm had 27 hours of this extreme velocity on April 11th and 12th, averaging in excess of 150 miles per hour for six hours.

The United States Signal Service has made a comparison of the wind velocity on the summit with the sea-coast at Portland, Maine, and finds that there is an increase of nine or ten percent in velocity for each 100 feet of elevation.

The effect of the wind becomes of paramount importance in connection with the growth and development of scrub, especially at tree line. The tremendous sweep of wind permits deep freezing of the soil and a subsequent dry-killing of plant life in winter. The settling of cold air in the ravines, such as Tuckerman, chills the surroundings and seriously affects forest growth, more-

over being largely responsible for late spring and early fall frosts (Monahan, 1933b).

Convectional Currents. As indicated elsewhere, a considerable proportion of the species of insects recorded from the higher altitudes of the range are lowland forms that have been transported to the summits by the aid of convectional currents of air. During the summer daylight, the earth is a much better absorber of the sun's rays than is the air, and thus attains a higher temperature. By conduction, the layer of air resting upon the earth becomes heated, and a portion of this warmer, lighter column expands aloft, thereby decreasing its own pressure at the surface while increasing that of the adjacent cooler air. This causes a lifting of the warmer air column by the heavier, cooler settling air which flows in at the surface to displace it. The upward flow of this heated air carries with it the numerous flying insects of the lower altitudes.

Light.—The effect of light on plant and animal organisms at high altitudes has received considerable attention. The study of ultra-violet radiation on Washington (September 9-15, 1935) by Brooks and Wexler is of interest. These authors have compared Washington with the station at Blue Hills, Massachusetts (altitude 650 feet) (Brooks and Wexler, 1937, 1938). Their summary is as follows:

1. Higher values of ultra-violet radiation on Mount Washington than those on Blue Hill by about 35 percent.

2. On Mount Washington, the percentage of ultra-violet radiation received direct from the sun is 54 percent of the total from sun and sky at noon; at Blue Hill, 48 percent.

3. Remarkable variability of ultra-violet radiation on Mount Washington on a cloudy day, due to the fact that cloud masses usually envelope the summit.

4. The total amount on a cloudy day is generally less than from the sky alone on a clear day.

5. The percentage of the total ultra-violet radiation from sun and sky which comes from the sun direct is nearly constant for four hours at mid-day.

4. Faunal Areas or Life Zones

From the very first scientific expedition to Mount Washington, it was noted that, as one ascended the mountain, definite zones of vegetation were encountered. The Reverend Dr. Manasseh Cutler, as early as 1784, recognized three such zones, — *1st*, Covered with a thick growth of wood; *2nd*, with mosses and a variety of other small vegetables; the *3rd*, above the limits of vegetation, covered ten or eleven months of the year with snow (Life, Journals and Correspondence of Rev. Manasseh Cutler, 2:273; 1888).

Dr. Jacob Bigelow (New England Journ. Medicine and Surgery, 5:332-337; 1816) recognized the following: *1*, The region of forest trees, up to 4,000

feet; *2*, A region of dwarf evergreens, 4,000-5,000 feet; *3*, An alpine region of 5,000-6,225 feet.

Edward Tuckerman (*In* King's, White Hills, 1868:232) writes: "Botanists designate the highest bald district, with the heads of the ravines descending from it, as the *alpine region*, and have sometimes spoken of a small tract intermediate between the two, but still imperfectly characterized, as the *subalpine region*."

Scudder (1874) differentiated between: *1*, Mountain forest (Canadian). *2*. Subalpine scrub (Hudsonian). *3* Alpine rocks (Labradorian or Subarctic). This same year (1874b, 1874c) Scudder provided colored maps showing the limits of the alpine and subalpine districts in the Presidentials. He further discussed this as follows (1874c:7): "The *subalpine* district is the region of the dwarfed spruce, and includes the heads of the deepest ravines; the *alpine* is characterized by naked, broken masses of rock, excepting on the level spots, where sedges conceal them. *Œneis semidea* is confined to this highest district." In 1887, Scudder distinguished the alpine summits as *upper alpine*, the scrub zone as *lower alpine*.

Hayward (1885) classifies the White Mountains in four "tolerably distinct faunæ." I have placed the Merriam equivalent following each of these in parenthesis. *1*. The first, called *alpine*, is restricted to the summits of the higher mountains *(Arctic-Alpine)*. 2. The second, which is termed *subalpine*, is confined to the neighborhood of the timber-line *(Hudsonian)*. 3. The third occupies the greater part of the country below and is the ordinary fauna of northern New England *(Canadian)*. *4*. Confined to the immediate vicinity of the larger river-bottoms, and is essentially identical with that of eastern Massachusetts *(Transition)*. It will be seen that the above very closely approximates our present conception, based on the Merriam life zones, formulated during the 1890's (Merriam, 1893, 1894, 1898).

Dice (1938), basing his opinion on a study of the mammals, recognizes only six of the Merriam life zones or biotic provinces, in eastern North America. He eliminates the Transition zone, uniting it with the Canadian. Dice, as well as several others, place the northern limit of the Canadian zone at the mouth of the Gulf of Saint Lawrence, thus including Gaspé and all of New Brunswick. On the basis of insect distribution, this northern boundary scarcely seems tenable, certainly not to include the northern shore and elevated central portions of Gaspé which are evidently Labradorian and hence to be referred to the Hudsonian. If this northern limit of the Canadian zone is admitted, its upper portion would be raised considerably over the figure given in this paper, probably to the floor of Tuckerman Ravine, or approximately 4,000 feet. Such a conception would limit the Hudsonian zone to a relatively narrow belt between the 4,000 and 5,000 foot levels, virtually restricting it to the floors and headwalls of the ravines. On the basis of physical conditions, particularly temperature, and considering the plants and insects that are deemed to be indicators of the zones in question, I am inclined to place a somewhat lower limit to this border between the Hudsonian and Canadian zones, possibly as

low as 3,000 feet along the eastern side, as along the Tuckerman trail. The reasons for this opinion are given more in detail under the discussion of the Hudsonian zone. Throughout my work on zonal distribution, as it pertains particularly to the Tipulidae, I have felt the need of recognizing subzones or divisions and it has seemed desirable to differentiate, for example, high or low Canadian, high or low Hudsonian, and in similar manner.

Arctic-Alpine or Alpine zone.—This includes the rocky summits of the Presidential Range. As first restricted by Scudder (1874b:338), the true alpine zone includes only the upper one hundred or two hundred feet of the summits of the cones of Mounts Adams and Jefferson and some seven to eight hundred feet of Mount Washington. On his maps (Scudder, 1874b, 1874c), the alpine areas thus appear as three islands,of which that surrounding Washington is much the largest, but from this early conception, does not reach the Lakes of the Clouds or the head wall of Tuckerman Ravine. Later, Scudder (1887) provided a second and much more accurate map where the Upper Alpine or Rocky District was differentiated from his Lower Alpine or Scrub District and, as shown. forms a continuous area extending from Bigelow's Lawn near the Lakes of the Clouds northward almost to Star Lake near the Madison Springs. This latter conception of a more extended and continuous alpine zone has been confirmed by several later scientists and has been well-expressed by Antevs (1932):

> The alpine region of the Mt. Washington Range extends for eight miles along the crest of the ridge, or from Mt. Franklin to Mt. Madison, and varies in width from a few hundred yards to about a mile. In vertical direction it comprises all land lying above the scrub-forest line at altitudes varying from 4,800 to 5,200 feet.

It seems certain that the limits of the Alpine zone, as above expressed, are approximately correct, since the plants and animals that we must consider as being indicators of the zone occur throughout the area as defined above. Thus, such eminently characteristic alpine plants as *Loiseleuria procumbens* (L.) Desv., *Phyllodoce coerulea* (L.) Bab., *Cassiope hypnoides* (L.) D. Don., and *Diapensia lapponica* L., occur in suitable localities along the entire crest of the range. Some of the finest cushions of *Diapensia* are to be found between Star Lake and the Madison Springs at near the lower altitudinal range specified by Antevs. Mrs. Slosson (1894b:2) considered the "alpine line" to lie at 4,000 feet but this is evidently too low for true alpine conditions, with the possible exception of the "Horn" of Chandler Ridge, at about 4,100 feet, as further discussed under the subject of "Tree Line." As a basis upon which to work, the altitude of from 4,800 to 5,200 feet, depending on several factors of exposure and gradient, together with the indicator species of plants and insects listed below, may be taken as features characteristic of the zone. Generally speaking this corresponds very closely with the upper limit of tree line, as discussed later.

Scudder's short description (1874b:342-343) of the Arctic-Alpine zone as it occurs on the Presidentials is so characteristic that it can scarcely be improved:

> These regions are confined solely to the summits of the very highest mountains, all

comprised within a few square miles, exposed almost continuously to the very fiercest gales; they are covered by interminable broken rock-masses, concealed in part by a scanty layer of mould, supporting either sedges, or stunted juniper-like spruces, whose gnarled and spreading branches creep along the ground.

The barren exposed summits of the range have been described variously as being fell-field or even tundra. The fell fields include the barren rocky outcrops themselves, with their scanty soil and a very sparse flora and fauna. According to Antevs (1932), *tundra* in its restricted sense of treeless, wet moorland with predominating mosses and lichens in an arctic climate with moist air, does not exist on the range. He classifies the various plant formations into different types of alpine heaths, heath-meadows, bogs, bog-meadows, and scrub thickets, where one or more of the alpine species of plant dominate, with an admixture of other forms, and with numerous *Cladonia* lichens and some mosses. Thus among the alpine heaths, he differentiates (1) a *Juncus trifidus-Carex concolor* heath; (2) *Juncus trifidus-Carex concolor-Cladonia*-Moss heath; (3) *Carex concolor-Cladonia* heath; (4) *Carex concolor-Cladonia*-Moss heath; (5) *Diapensia* heath; (6) *Salix-Carex-Arenaria-Cladonia*-Moss heath; (7) *Vaccinium-Carex-Cladonia*-Moss heath; and (8) a *Cladonia*-Moss heath. The heath-meadows, protected from sweeping winds, include both heath shrubs and meadow herbs of many species. True bogs occur in the vicinity of the Lakes of the Clouds and around Star Lake, a few hundred feet above the Madison Springs. Bog-meadows, with much sphagnum, occur and support a rich and varied flora of arctic and hudsonian plants. On the range there are no extensive alpine meadows, such as are so characteristic of the European Alps.

A detailed study of the insects of these various habitats should be made. With relatively few exceptions, we have no specific restricted station for the approximately 3,000 insect species so far recorded from higher altitudes on the range.

Arctic Plants of the Presidential Range (M. L. Fernald)

Lycopodiaceae: *Lycopodium Selago* L.
Gramineae: *Poa laxa* Haenke
Poa glauca Vahl
Agropyron violaceum (Hornem.) Lange
Deschampsia atropurpurea (Wahlenb.) Scheele
Calamagrostis hyperborea Lange
Calamagrostis neglecta (Ehrh.) Gaertn., Meyer and Scherbius
Calamagrostis canadensis Langsdorfii (Link) Trin.
Agrostis borealis Hartm.
Phleum alpinum L.
Hierochloë alpina (Sw.) R. and S.
Hierochloë odorata (L.) Wahlenb.
Cyperaceae: *Scirpus caespitosus callosus* Bigelow
Eriophorum spissum Fernald
Carex capitata L.
Carex scirpoidea Michx.
Carex brunnescens Poir.
Carex concolor R. Br.
Carex capillaris L.
Juncaceae: *Juncus trifidus* L.
Luzula spicata (L.) DC.
Luzula confusa Lindeb.
Luzula parviflora (Ehrh.) Desv.
Salicaceae: *Salix Uva-ursi* Pursh
Salix herbacea L.
Salix planifolia Pursh
Salix argyrocarpa Anderss.
Betulaceae: *Betula glandulosa* Michx.
Betula papyrifera minor (Tuckerman) Fern.
Alnus crispa (Ait.) Pursh.
Polygonaceae: *Oxyria digyna* (L.) Hill
Polygonum viviparum L.
Caryophyllaceae: *Arenaria groenlandica* (Retz) Spreng.

Silene acaulis exscapa (All.) DC
Cruciferae: *Cardamine bellidifolia laxa* Lange
Saxifragaceae: *Saxifraga rivularis* L.
Rosaceae: *Sibbaldia procumbens* L.
Potentilla tridentata Ait.
Potentilla Robbinsiana Oakes
Geum Peckii Pursh
Rubus Chamaemorus L.
Empetraceae: *Empetrum nigrum* L.
Violaceae: *Viola palustris* L.
Viola labradorica Schrank
Onagraceae: *Epilobium lactiflorum* Haussk.
Epilobium Hornemanni Reichenb.
Epilobium palustre labradoricum Haussk.
Ericaceae: *Rhododendron lapponicum* (L.) Wahlenb.
Loiseleuria procumbens (L.) Desv.
Phyllodoce coerulea (L.) Bab.
Cassiope hypnoides (L.) D. Don.
Arctostaphylos alpina (L.) Spreng.
Vaccinium uliginosum alpinum Bigelow
Vaccinium pennsylvanicum angustifolium (Ait.) Gray
Vaccinium Vitis-Idaea minus Lodd.
Diapensiaceae: *Diapensia lapponica* L.
Scrophulariaceae: *Veronica alpina unalaschcensis* C. and S.
Euphrasia Williamsii Robinson
Rhinanthus borealis (Sterneck) Chabert
Lentibulariaceae: *Pinguicula vulgaris* L.
Compositae: *Gnaphalium supinum* L.
Achillea Millefolium nigrescens E. Meyer
Prenanthes Boottii (DC) Gray

Of the 63 species, 48 also occur in Europe, 45 in Asia, and 44 in Eurasia. The great majority, 57, reach their southern limit in America in the White Mountains. Only three species, with two additional races, are restricted to the Range: *Potentilla Robbinsiana, Geum Peckii* and *Euphrasia Williamsii*, with *Paronychia argyrocoma albimontana* Fern. (Illecebraceae) and *Houstonia caerulea Faxonorum* Pease & Moore (Rubiaceae). The Hudsonian zone plants total about 125 species that have been listed in detail by Pease (in Antevs, 1932); many of these latter penetrate into the Arctic zone above, while, conversely, several of the 63 Arctic plants above listed occur in suitable places below the altitude of tree line and so well within the Hudsonian zonal limits, or even further south. It is noteworthy that no fewer than five of the Arctic plants listed reach the general latitude (35°-36° North) of the Great Smoky Mountains in North Carolina-Tennessee.

Arthropoda of the Arctic-Alpine Zone

Due to the insufficiency of data, only a relatively few spiders and insects that presumably characterize the highest zone of the range are here recorded.

Arachnida:
Micryphantidae: *Cochlembolus alpinus* Banks.
Argiopidae: *Araneus carbonarius* (L. Koch) (*packardii* Thor.).
Lycosidae: *Lycosa albohastata* Emerton.
Lycosa pictilis Emerton.
Pardosa glacialis Thorell
Pardosa groenlandica Thorell
Pardosa luteola Emerton
Pardosa muscicola Emerton
Pardosa tachypoda Thorell
Pardosa uncata Thorell

Hexapoda: Plecoptera

Dictyopterygella washingtoniana Hanson. In the outlet of the Lakes of the Clouds, head-waters of the Ammonoosuc River.

Perlodes margarita Alexander (Alexander, 1936 a). At the foot of the glacier in Tuckerman Ravine, under strict arctic conditions.

Perlodes slossonae Banks. A Hudsonian to high Canadian species, *Leuctra variabilis* Hanson, likewise occurs at the Lakes of the Clouds outlet.

COLEOPTERA. Our knowledge of the beetles of the higher altitudes is better than that of almost any other order, due to the records of Bowditch (1896), Sherman (1910), Mrs. Slosson, and others. Sherman (1910: 175) lists from Labrador 169 species of beetles, of which 95 are also known to occur on Mount Washington or elsewhere in the White Mountains.

Of the various lists of Coleoptera (Austin, Gardiner), Bowditch (1896) summarized all earlier papers through the year 1895 and further attempted to indicate the species that he believed to be truly alpine forms. His list of Mount Washington beetles includes 659 species, representing 52 families, the largest and most important being as follows: Carabidae, 89; Staphylinidae, 72; Elateridae, 63; Cerambycidae, 59; Chrysomelidae, 42; Dytiscidae and Lampyridae, 33 each; Curculionidae, 28; Coccinellidae, 22; Silphidae, 20; Scarabaeidae and Hydrophilidae, 17 each. It is particularly interesting to note that in the family of predacious diving beetles, Dytiscidae, Bowditch records no fewer than 23 species from the Lakes of the Clouds at 5,000 feet. Bowditch's differentiation between "alpine" and "summit" records may be an attempt to restrict the latter term to those species that are obviously lowland forms carried to the summit by convectional air currents.

The list of beetles given below includes the more evident Arctic-Alpine species. It is somewhat noteworthy that such a large proportion belong to the family of ground beetles, Carabidae. Among the numerous other beetles recorded from the higher altitudes, there will probably be included several other alpine forms that have not been detected in the present survey.

Carabidae: *Carabus chamissonis* Fisch.
Loricera caerulescens (L.)
Notiophilus aquaticus (L.)
Notiophilus borealis Harris
Notiophilus sylvaticus Esch.
Nebria sahlbergi Fisch.
Nebria suturalis Lec.
Bembidion (Diplocampa) cautum Lec.
Bembidion (Lopha) mutatum G.&H.
Bembidion (Melomalus) simplex Hayw.
Bembidion (Notaphus) versicolor (Lec.)
Bembidion (Peryphus) nitens Lec.
Bembidion (Peryphus) scopulinum (Kby)
Amerizus oblongulus (Mann.)
Patrobus septentrionis Dej.
Trechus borealis Schffr.
Bothriopterus adstrictus (Esch.) (*vitreus* Dej.)
Bothriopterus luczotii (Dej.)
Cryobius hudsonicus Lec.
Cryobius mandibularis Kby.
Cryobius vindicatus Mann.
Celia erratica Sturm
Curtonotus brunnipennis Dej.
Curtonotus cylindricus Lec.
Stereocerus haematopus (Dej.)
Calathus ingratus Dej.
Platynus stygicus Lec.
Cymindis unicolor Kby.
Harpalus laticeps Lec.
Harpalus varicornis Lec.
Trichocellus cognatus Gyll.
Haliplidae: *Haliplus cribrarius* Lec.
Dytiscidae: *Deronectes griseostriatus* (DeG.)
Ilybius discedens Sharp
Agabus anthracinus Mann.
Agabus congener Payk.
Agabus infuscatus Aubé
Agabus leptopsis Lec.
Agabus punctulatus Aubé
Agabus tristis Aubé
Staphylinidae: *Acidota quadrata* Zett.
Quedius fulvicollis Steph.
Tachinus parallelus Horn
Byrrhidae: *Simplocaria metallica* Sturm
Byrrhus cyclophorus Kby.
Byrrhus geminatus Lec.
Byrrhus kirbyi Lec.
Cantharidae (Lampyridae):
Cantharis curtisi Kby.
Podabrus diadema (Fabr.)
Podabrus extremus Lec.
Podabrus laevicollis (Kby.).
Podabrus piniphilus (Esch.)
Elateridae: *Cryptohypnus sanborni* Horn
Ludius costalis (Payk.) (*pictus* Cand.)
Ludius estriatus (Lec.)
Sericus incongruus (Lec.)
Melandryidae: *Scotodes americanus* (Horn)
Mordellidae: *Mordella borealis* Lec.
Cerambycidae: *Acmaeops pratensis* (Laich.)
Chrysomelidae: *Phytodecta pallida* (L.)
Crepidodera robusta Lec.

LEPIDOPTERA. The relatively few species listed below seem to be those that most characterize the alpine zone of the Presidentials. It seems certain that several additions to this list will be made, especially among the micro-lepidoptera.

Tortricidae: *Tortrix moeschleriana* Wocke
Geometridae: *Eupithecia cretaceata* Packard
Phalaenidae: (Noctuidae)
Euxoa dissona dissona (Moeschl.)
Euxoa dissona opipara (Morr.)
Pachnobia tecta (Hübn.)
Pachnobia wockei Moeschler
Anomogyna elimata (Guen.)
Anomogyna imperita (Hübn.)
Archanarta quieta (Hübn.)
Anarta melanopa Thunb.
Autographa interrogationis vaccinii Hy.-Edw.
Autographa interrogationis u-aureum Guen.
Liparidae: *Byrdia rossii* (Curt.) (Grote, 1876)
Satyridae: *Oeneis melissa semidea* (Say) "White Mountain Butterfly"

The most famous single insect of the range is undoubtedly the so-called "White Mountain Butterfly." The account of its discovery and subsequent description by Thomas Say has been given later in this paper. Virtually all of the many entomologists who have visited the summits from late June to early August have observed or captured this interesting species. On sunny days it is often very common and much in evidence, occupying the higher altitudes, descending at least as low as 4,600 feet (Skinner, 1919). Scudder (1889: 134-148) has described it and its habits in great detail in an account that has been characterized as being a classic. Morrison (1875: 43) draws an interesting picture of this arctic butterfly feeding upon the nectar of an arctic heath, *Cassiope hypnoides*, in company with an arctic moth, *Anarta melanopa*, among the great rocks near the Summit House.

Suggestions have been made that steps be taken to protect the species from overcollecting (Carpenter, 1901), but several capable observers have stressed the fact that because of the ruggedness and inaccessibility of the country inhabited, the species is in no danger from human agencies (Ottolengui, 1901; Slosson, 1901; Fox, 1939). The species recurs at high altitudes in the Rocky Mountains of Colorado. On Mount Katahdin, Maine, 160 miles northeast of Mount Washington, occurs a second, entirely distinct, species, *Oeneis polixenes katahdin* (Newcomb) (Newcomb, 1901, 1902; Fox, 1939), similarly a glacial relict.

DIPTERA. It is probable that among the hosts of smaller members of this order occurring in the alpine region that many forms restricted to this zone will be found, but in our present state of knowledge these cannot be safely indicated. Later in this report, under the discussion of the Diptera of the Hudsonian zone, numerous species are listed, some of which will be found to be more truly alpine forms. In his preliminary list of the Diptera of Labrador, Johnson (1929) reports about 170 species, several of which occur on Washington or even further to the south.

Tipulidae:

Tipula (Nitiditipula) pachyrhinoides Alex.

Described from Mount Washington, exact locality unknown. From its distribution in Canada, I would believe the species to be alpine or high Hudsonian.

Tipula (Oreomyza) insignifica Alex. (Alexander, 1924, 1936 b).

Described from a unique male taken in the Alpine Garden, 5,000-5,500 feet, September 21, 1919. Later found in numbers at the Madison Springs, Star Lake and Lakes of the Clouds, in late August. Elsewhere known only from high altitudes on Katahdin (Baxter Spring to Summit, September 2, 3, 1939 (*A. E. Brower*).

Tipula (Oreomyza) nebulipennis Alex. (Alexander, 1934, 1936b)

Known from Labrador and Gaspé. Common on the Presidentials, from 4,700 feet and upward, especially at and near the Lakes of the Clouds.

Nephrotoma penumbra Alex. (Alexander, 1934, 1936b)

Described from the alpine zone of the range; likewise occurs at high altitudes on Katahdin. Abundant in the Alpine Garden in early July, the immature stages in cushions of *Diapensia lapponica*. This is presumably the same fly recorded by Mrs. Slosson (1895c) as *vittula* (Loew).

Limonia (Dicranomyia) halterella (Edwards)

One of the most interesting discoveries in recent years. Headwall of Tuckerman Ravine, abundant along a small stream immediately below the crest, altitude 5,000 feet, August 28, 1938, resting on flowers of various Composites. Elsewhere known only from three stations in Scotland.

Dicranota (Plectromyia) petiolata (Alex.)

Headwall of Tuckerman Ravine, immediately below the crest, near the station of the last-discussed species; altitude 5,000 feet, in late August. Elsewhere known from Gaspé and the higher Rockies of Colorado.

Phyllolabis lagganensis Alex. (Alexander, 1936b)

Mount Madison, along Snyder Brook, altitude 4,200 feet, August 26, 1935. Elsewhere only from the Canadian Rockies. Despite the relatively low altitude, I am inclined to consider this species as being a member of the lowest alpine zone rather than high Hudsonian.

Besides the species discussed above, three other arctic-alpine Tipulidae may occur on the range. *Tipula (Oreomyza) subserta* Alex., described from Labrador, has been taken on the summit of Katahdin by Dr. A. E. Brower. *Tipula (Oreomyza) broweri* Alex., is an autumnal species, still known only from the alpine summits of Katahdin, where it was taken by Dr. Brower. *Archilimnophila harperi* (Alex.), described from Alberta, has been taken in the higher Adirondacks of New York.

Hudsonian zone.—This zone on the Presidentials lies below the barren summits, occupying the upper ravines and gulfs to the limits of their head walls. In Labrador (Townsend and Allen, 1907: 282-287), the upper limits of the zone correspond closely to tree line and this is interpreted in a similar manner for these mountains. The lower limits of the Hudsonian are much more difficult to decide and, as already stated, there is no common agreement as to the point of its merging with the Canadian.

There are a few species of Tipulidae that I consider as being lower Hudsonian forms, including *Tipula (Schummelia) idei* Alex., *Pedicia (Nasiternella) hyperborea* (O.S.) and *Dicranota (Paradicranota) iowa* Alex. Along the Tuckerman trail, such forms range as low as the Cutler River crossing or approximately 3,000 feet. If these are true indicators of the lowest Hudsonian or even the highest Canadian, the lower edge of the zone will be delimited somewhere between the 3,000 and 3,500 foot level, or somewhat below Hermit Lake. The boreal plants of this zone have been listed in full by Pease (in Antevs, 1932:82-84); besides these, other species from the Canadian zone invade the Hudsonian from below while alpine types persist at suitable stations well within the limits of the zone, as on the headwalls of Tuckerman and Huntington Ravines. Detailed stations for many such plants have been given by Pease (1924).

There appear to be numerous species of Arachnida and Hexapoda that characterize this zone but only a few of these may be discussed here. It is certain that many more will be determined as further studies are made.

ARACHNIDA.

Amaurobiidae: *Amaurobius borealis* Emerton

Gnaphosidae: *Gnaphosa brumalis* Thorell

Theridiidae: *Theridion montanum* Emerton

Linyphiidae, *Bathyphantes alpina* Emerton

Micryphantidae: *Linyphia nearctica* Banks

Tmeticus bidentatus Emerton

Tmeticus montanus Emerton

Cornicularia clavicornis Emerton

Microneta olivacea Emerton

Argiopidae: *Zilla montana* C. Koch

Agelenidae: *Cryphoeca montana* Emerton

Lycosidae: *Pardosa*, six species listed under the Arctic Alpine zone, where they likewise occur.

ORTHOPTERA. The wingless White Mountain Locust, *Zubovskya glacialis glacialis* (Scudder), formerly placed in *Pezotettix* and *Podisma*, is the most characteristic member of the order in this zone (Scudder, 1863, 1874 b, 1898) and appears to be virtually restricted to this zone and the higher Canadian. It is widely distributed over the range, from Mount Madison to the floor of Huntington Ravine; it rests upon the rocks and shrubs, becoming adult by mid-August or slightly later. Considering its wingless condition it is surprisingly active. The same subspecies has been taken in cold bogs virtually at sea level on Mount Desert island, Maine.

Other Locustidae (Acrididae) of the higher zones include the following:

Mecostethus gracilis (Scudder)
Melanoplus borealis (Fieber)
Acrydium granulatum incurvatum Hancock
Acrydium hancocki Morse

HEMIPTERA-HOMOPTERA
Cicadellidae: *Ophiola arctostaphyli* (Ball)

LEPIDOPTERA. The most discussed butterfly of the zone and one virtually restricted to it, is a fritillary, *Brenthis montinus* (Scudder) (Scudder, 1863, 1874b, 1889, 1895). According to Scudder, this likewise occurs in Gaspé and in southern Labrador. A related *Brenthis, B. aphirape* (Hübn.) has been found recently in the Hudsonian zone of Mount Katahdin, Maine (Klots, 1939).

DIPTERA

Tipulidae: *Tipula (Oreomyza) idei* Alex.
Pedicia (Nasiternella) hyperborea (O.S.)
Dicranota (Paradicranota) iowa Alex.
Dicranota (Plectromyia) modesta (O.S.)
Dactylolabis pemetica Alex.

Chironomidae: *Palpomyia slossonae* (Coq.)
Anatopynia heteropus (Coq.)
Psilotanypus turpis (Zett.)
Eutanypus borealis Coq.
Cricotopus slossonae Mall.
Camptocladius minimus (Meig.)
Orthocladius sordidellus (Zett.)

Cecidomyidae: *Porricondyla papillata* Felt
Dirhiza montana Felt

Mycetophilidae: *Bolitophila montana* Coq.
Boletina groenlandica Staeg.

Bibionidae: *Hesperinus brevifrons* Walk.
Bibio fumipennis Walk.
Bibio vestitus Walk.

Xylophagidae: *Arthroceras leptis* O.S.
Xylophagus nitidus Adams

Rhagionidae: *Ptiolina edeta* (Walk.)
Symphoromyia montana Ald.

Asilidae: *Cyrtopogon lyratus* O.S.
Laphria altitudinum Brom.

Dolichopodidae: *Argyra obscura* VD
Rhaphium slossonae (Johns.)
Neurigona viridis VD
Dolichopus brevicauda VD, Cole & Ald.
Dolichopus dasypodus Coq.
Dolichopus stenhammari Zett.
Dolichopus xanthocnemus Loew

Empididae: *Trachypeza winthemi* Zett.
Ardoptera irrorata (Fall.)
Hormopeza brevicornis Loew
Rhamphomyia clauda Coq.
Rhamphomyia expulsa Walk.
Rhamphomyia longipennis Loew
Rhamphomyia rustica Loew
Rhamphomyia setosa Coq.

Phoridae: *Trupheoneura vitrinervis* Mall.
Paraspiniphora slossonae Mall.
Megaselida subobscurata Mall.

Pipunculidae: *Pipunculus alpinus* Cress.
Pipunculus trichaetus Mall.

Syrphidae: *Ferdinandea nigripes* O.S.
Melanostoma confusum Curr.
Epistrophe contumax O.S.
Epistrophe arcticus (Zett.)

Tachinidae: *Iconomedina washingtonae* (Coq.)
Mauromyia pulla Coq.
Phylacteropoda tarsalis (Coq.)
Apinops atra Coq.
Psalidopteryx slossonae Towns.

Anthomyidae: *Phaonia protuberans* Mall.
Trichopticus spiniger Stein
Trichopticus inocuus Zett.
Hydrotaea occulta Meig.
Helina neopoeciloptera Mall.
Spilogona argenticeps Mall.
Spilogona monticola Mall.
Hydrophoria arctica Mall.
Bithoracochaeta leucoprocta (Wied.)
Hoplogaster morrisoni Mall.

Scatophagidae: *Microprosopa volucricaput* (Walk.)

Microprosopa haemorrhoidalis Meig.
Acanthocnema nigrimana Zett.
Scatophaga monticola Mall.
Gimnomera tarsea Fall.
Helomyzidae: *Tephrochlamys flavitarsis* Darlingt.
Sciomyzidae: *Tetanocera rotundicornis* Loew

At Hermit Lake (3,650 feet) some interesting species of dragon flies, Odonata, are found, including species of *Aeschna* (*A. canadensis* E. M. Walker, *A. juncea* L., *A. caerulea septentrionalis* Burm., and *A. umbrosa* E. M. Walker) and *Leucorrhinia*, spp.

For several hundred vertical feet at the general altitude of Hermit Lake, an unusually abundant and dense growth of ground mosses occurs, comprised especially of *Hylocomium splendens* (Hedw.) B.S.G., and *Calliergonella Schreberi* (B.S.G.) Grout. These cover all prostrate trunks and exposed boulders and provide habitats for many insect species. The only comparable dense growths of *Hylocomium* that I have ever seen in eastern North America are at high altitudes on Mount Marcy in the Adirondacks of New York, and in the Canadian zone of the highest mountains of the Great Smokies, especially the summit of Mount Leconte, Tennessee.

Merriam (1898) indicates that the Hudsonian zone may recur on these highest summits of the southern Appalachians. At the very highest altitudes in the Great Smokies of the North Carolina-Tennessee border, I have seen no evidence of true Hudsonian conditions, the Fraser Fir-Red Spruce forests being definitely Canadian. Various species of northern herbs, including *Clintonia borealis* (Ait.) Raf., *Maianthemum canadense* Desf., *Oxalis montana* Raf., *Cornus canadensis* L., *Chiogenes hispidula* (L.) T. & G., and many others, that occur in these high coniferous forests are those that, in the north, are equally at home in the Canadian and lower Hudsonian zones. The presence of Mountain Ash, *Pyrus americana* (Marsh.) DC, along the higher ridges of the Smokies gives a more definite impression of the Hudsonian zone in these southern mountains but this seems negatived by the co-association with Sweet Buckeye, *Aesculus octandra* Marsh., and other lower Transition or Austral species. Similarly, the various arctic relict plants of these southern mountains (*Lycopodium Selago* L., *Agrotis borealis* Hartman, *Scirpus caespitosus callosus* Bigelow, *Alnus crispa* (Ait.) Pursh., and *Potentilla tridentata* Ait.) can scarcely be held to be sufficient to indicate Hudsonian conditions. As concerns the Tipulidae, even the highest altitudes of these southern mountains appear to support species that cannot be considered as being more than Canadian forms (as, for example, in the Pediciini, *Pedicia (Pedicia) margarita* Alex., *Pedicia (Tricyphona) auripennis* O.S., *Pedicia (Tricyphona) calcar* O.S., *Dicranota (Rhaphidolabis) rubescens* (Alex.), *Dicranota (Plectromyia) confusa* (Alex.), and others).

It is very certain that if the southern Appalachians support Hudsonian elements, the lower limits of this zone in the Presidentials lie even lower than has been suggested in this report.

Tree line.—Tree line is one of the most interesting habitats to be found on the range. Unlike our western mountains, there is no distinct timberline, where trees often attain a considerable size close to their upper limit (Griggs,

1938). In the Presidentials, tree line is where the arborescent species become reduced to dwarfed or prostrate shrubs, and, by degrees, bcome further reduced in size and finally form prostrate carpets. The tree species of this upper limit consist primarily of balsam fir, *Abies balsamea* (L.) Mill., black spruce, *Picea mariana* (Mill.) B.S.P., and alpine birches, *Betula papyrifera minor* (Tuckerman) Fern., and *Betula glandulosa* Michx., together with occasional alpine species of willows, *Salix* spp. Both larch and juniper, while being reported from the range, are very uncommon and of no ecological significance. Many of the tree line trees are of great age despite their reduced size; the oldest trunk measured by Griggs showed 110 annual rings and since this species here reproduces chiefly by layering, a given trunk may represent only a fraction of the total life of the tree. None of the trunks measured by Antevs had attained a century of growth. O'Kane (1924) records a spruce only three feet in height, with a trunk four inches by five inches in diameter, of an age of 363 years.

The exact location of tree line depends on various factors, such as direct exposure to wind, position on the range, protection by snow drifts, whether on exposed ridges or in sheltered ravines, edaphic conditions, and probably others. Where affected by the wind, the trees show a gradual reduction in height, become massed in dense societies to afford mutual protection, and at their uppermost limits occur as clumps of dwarfs in local depressions and sheltered spots. The exact limits of tree line on the range have been detailed by Antevs (1932:71-73); in general, on the west or windward side the upper limit is between 4,800 and 5,000 feet; on the leeward side it attains to 5,200 feet. On the exposed Durand Ridge it terminates at 4,300 feet. Nowhere on the range does forest span a pass that lies above 4,600 feet. Griggs (1939) notes that even as low as 4,100 feet, at the "Horn" on Chandler Ridge, there is no tree growth. He attributes this unusually low tree line primarily to the effects of the wind rather than to temperature due to localized cold spots. Measurements taken by means of Biram hand anemometers showed that the velocity of the northwest wind at the "Horn" corresponds almost exactly to that at the summit and was higher than that of other points much closer to the summit, such as the six-mile post (5,340 feet) and the seven-mile post (5,850 feet) of the Carriage road. A further important observation brought out by Grigg's work in 1939 was that the highest winds of the range occur on the lee rather than on the windward side. This is shown by the fact that in equally exposed situations, trees are much more severely deformed on the east than on the west side of the range, and further by the fact that the great hurricane of September 21, 1938 did much more damage on the northeast or lee side of the range than on the windward.

Altitude alone does not appear to affect tree shape, since Griggs (1938) reports trees as low as 4,100 feet in about the same conditions as those at 5,400 to 5,800 feet. The very highest tree noted, a deformed balsam, was above the 6,200 foot level or within one hundred vertical feet of the summit of Washington. The effects of wind and local protection by snow drifts have been detailed by Griggs. Toward the upper limits of tree growth, these dense

scrub thickets form almost impenetrable masses (Krummholz, puckerbush) that undoubtedly form the normal habitat for numerous species of insects and other animals.

Canadian zone.—The coniferous forest belt below the Hudsonian, including the lower forested slopes of the range to about the 1,200-1,500 foot levels. At Pinkham Notch Hut (2,000 feet), conditions are definitely of this zone.

Transition zone.—Within the limits of the White Mountain National Forest, this zone occurs in the major clearings, such as the Dolly Copp camp, a few miles south of Gorham, and others. In the valleys of the larger rivers, as the Androscoggin to the north and northeast, and the Ammonoosuc to the west, conditions are definitely transitional.

5. Exploration of the Range

General.—The first ascent of Mount Washington was by Darby Field, who climbed the mountain on two occasions in 1642. During the succeeding century and a half, hardy pioneers penetrated into the region and gradually established the first homes in the two principal notches that isolate the range. The first scientific expedition was that of the Reverend Dr. Manasseh Cutler-Jeremy Belknap, who with three others, ascended the mountain in July 1784, via the route now known as Cutler River-Boott Spur. In July 1804, Cutler, accompanied by the entomologist Peck, made a second trip to the range. During the first half of the Nineteenth Century, many scientists, especially botanists, explored the higher altitudes, these including Jacob Bigelow, Francis Boott, William Oakes, and Edward Tuckerman. The names of these pioneers are now connected with conspicuous and well-known landmarks of the range, such as Cutler River, Bigelow Lawn, Boott Spur, Oakes Gulf, and Tuckerman Ravine.

Entomological.—Evidently the first entomologist to ascend the mountain was William Dandridge Peck, as above mentioned. It seems certain that Peck failed to discover the White Mountain Butterfly and the early specimens of this seem to have been taken by the distinguished English naturalist, Thomas Nuttall, on August 12, 1824, and by Dr. Charles Pickering in July 1825 and again in late July, 1827. This material constituted the basis for Say's description of the species in 1828. The botanist, William Oakes, found the butterfly abundant in late June, 1826, on his second trip to the mountain. One of America's best-known entomologists, Thaddeus W. Harris, spent the first half of August 1853 making a trip through Pinkham Notch and to the Glen House but did not ascend into the higher mountains. The first entomologist to make extensive collections in the alpine region of the range was Samuel Hubbard Scudder, by many considered to be America's greatest entomologist. Scudder ascended the mountain in July 1859 on the first of his many expeditions to Mount Washington and his accounts of certain of the species, especially the White Mountain Butterfly and the Wingless Locust, provide us with delightful pictures of certain of these trips.

Following the close of the Civil War, more and more entomologists visited

the alpine region, including the somewhat noteworthy trip of F. G. Sanborn in 1869. In 1874, the enthusiastic young members of the newly formed "Cambridge Entomological Club" announced plans for a collecting trip to the region. According to B. P. Mann (Psyche, 1:6; 1874): "Some of the members of the Club, with other entomologists, will spend several weeks this summer on Mt. Washington, in a camp one-fourth of a mile below the Halfway House, and two hundred feet from the carriage road. They expect to leave Boston June 25. Other entomologists are invited to join the party." The camp lasted from June 26 to July 11, 1874 (Morrison, l.c., 1:25; 1874). According to Emerton (1924), who has furnished an excellent figure depicting the camp and its environment, ten persons were in attendance, including the following who were to attain various degrees of entomological prominence: E. P. Austin, F. Blanchard, George Dimmock, J. H. Emerton, B. P. Mann, and H. K. Morrison. The success of this first camp encouraged the club members to hold a second one in July 1875, this latter evidently having been a great social success since it was attended by six club members and eighteen guests, of whom no fewer than fourteen were women. On these two expeditions, Morrison collected some 20,000 insect specimens which later were acquired by C. V. Riley and are now in the United States National Museum. Such specimens bear the simple label "White Mts.," without indication of state, date or altitude. Morrison, who was a prodigious walker and collector, evidently scoured the mountain from the camp site to the summits (Morrison, 1875b) and several of his captures have never been rediscovered in these mountains; these include the type specimen of a crane-fly, *Dicranota (Eudicranota) pallida* Alex., which, while never having been found again in the White Mountains, has lately been found on Mount Desert island, Maine.

Until 1890, the records of insects from the alpine regions of the Presidentials consisted almost solely of Lepidoptera (Grote, Morrison, Scudder) and Coleoptera (Austin, Bowditch, Gardiner). In the late 1880's Mrs. Annie Trumbull Slosson began her series of trips to the region, including almost unbroken annual visits to the summit of Washington (Slosson, 1890-1906). These trips resulted in the collection of many thousands of insect specimens which were submitted to specialists in the various orders and formed the basis for ten lists of "Insects taken in the alpine region of Mt. Washington"; Slosson, 1894b-1906. These papers include a total of somewhat over 2,000 species of insects, the exact number being uncertain because of the synonyms, *nomina nuda*, and mis-determinations in certain groups. All orders of insects, as well as the Arachnida, are represented. Although the material was collected entirely on the alpine regions of the mountain (5,000 feet and over), the majority of the included species are not forms characteristic of, nor restricted to, this highest zone but are lowland species carried by convectional air currents to the summit and there captured. The Summit House of the 1890's (built 1873; destroyed by fire 1908) had a wooden front that was painted white and proved a great source of attraction to insects. Mrs. Slosson (1893:250) writes: "On a clear day this has sunshine on it from morning till late afternoon." Bowditch (1895) amplifies this: "Borne by the wind, species from the adjacent country are carried over the mountain, and are collected in great numbers on the

Summit, so that a general list of summit captures includes not only the strictly Arctic fauna, but very many chance visitors. A warm day with a south wind produces a wonderful crop of beetles on the Summit; the air is filled with them; the white painted hotel is a great attraction for many, and the collector is kept busy merely looking over the walls of the buildings; these flights seem worthy of close study, i.e., direction, duration, times, etc., as indicating what goes on all over the country in a greater or less degree; here the mountain enables us to be in the midst of the flight and get an idea of the extent of the migration or moving about of species. Early in the season is much the best time for collecting, as the cold weather comes very early, and towards the end of July many species has disappeared. * * * Future collecting will doubtless add many small alpine species, and the 'Lakes of the Clouds' need careful dredging early in the season, to show their best array of water beetles." Still further discussing this occurrence of low-altitude species on the summit, Scudder (1895:80-81) writes: "In the first week of June I have found the great snow-patches at the very summit of Mt. Washington fairly peppered with numerous small insects, especially Coleoptera, Diptera, Hymenoptera, and Homoptera, prominent among which were thousands upon thousands of delicate-winged plant-lice. Besides these among the larger insects an *Acanthosoma*, perhaps *A. nebulosa*, swarmed on the hotel piazza, and every pool of water by the roadside was the grave of countless *Bibio femoratus*."

One of the chief means of capture adopted by entomologists is light collecting, using various types of traps and lanterns. As concerns this method on the summit, the following experiences of Mrs. Slosson (1893:250) are of interest: "There is no night collecting on the Summit. I have been there a great many times in all sorts of weather, but have never seen an insect fly after dark." Later (1894:271) she modified this opinion when she captured a few moths at light one evening at the Summit House. Arenberg (1939b) found insects attracted to light at the Mount Washington Observatory, some of these being eaten by toads.

During the present century, the alpine zone of the Presidentials has continued to attract the attention of many entomological students and collectors. The late Charles W. Johnson visited the range annually between 1913 and 1916, collecting in the alpine zone on each occasion. From June 24 to 29, 1913, he collected at Bretton Woods and along the Ammonoosuc River toward the Base Station, going to the summit of Mount Washington on the 30th. Between July 3rd to 9th, 1914, he stayed the the Glen House, collecting over the Alpine Garden on the 4th, at the Halfway House on the 6th, and in Tuckerman Ravine on the 8th. From July 15 to 29, 1915, Johnson again stayed at the Glen House, collecting at the Halfway House on the 16th, the Alpine Garden on the 21st, and in Tuckerman Ravine on the 21st and 28th. Between June 10 and 18, 1916, he was once more at the Glen House, collecting at the Halfway House on the 13th. Again on August 15, 1916, he collected at the Base Station, on the 16th in the Alpine Garden, and on the 17th at the Glen House. In his splendid basic list of the "Diptera of New England" (Johnson, 1925) are included all of his records, as well as the

approximately 500 species of Diptera recorded earlier by Mrs. Slosson, and the numerous scattered records of other students. Unfortunately for purposes of exact distribution on the range, the majority of Johnson's records are listed merely as Area No. 11, which included his entire "White Mountain Area," all of Coös county, New Hampshire, and adjoining counties to the south as far as Mount Chocorua. Thus it is impossible to differentiate the alpine and subalpine forms from the numerous records of low altitude captures. Although most of the Johnson specimens are preserved in the collection of the New England Society of Natural History and in the Johnson collection at the Museum of Comparative Zoölogy, Cambridge, very many have been scattered by exchange and it would be a difficult task to trace such records.

The curator of the entomological museum of the Massachusetts State College, Dr. Marion E. Smith, has made extensive collections of insects in the alpine region of the Presidentials. In 1939, the members of the staff of the Mount Washington Observatory, under the guidance of Mr. David L. Arenberg, secured approximately 1,000 specimens of insects, accompanied by data as to temperature, humidity and wind. Very generously these have been presented to the Massachusetts State College. This material included the hitherto unknown naiad of the rare alpine stone-fly, *Dictyopterygella washingtoniana* Hanson, still known only from the streams at the Lakes of the Clouds.

6. Future Entomological Work

As indicated in the preceding pages, although fully 3,000 species of insects have been recorded from the alpine region of Mount Washington, the majority of such records are so incomplete as to have limited value. For purposes of the future, specimens labelled merely "Mt. Washington" will have little significance. Fortunately the entire range has named geographical locations that will enable collectors to more exactly label their material. Thus, the various peaks with their ascertained altitudes; ravines and gulfs, with their own local named features; alpine lakes, springs and streams; established trails and buildings; the mile-posts along the upper half of the Carriage road, and similar features, all permit more exact labelling of specimens. Scudder (1895:150) anticipated this need of detailed lists of plants and insects, with exact stations, especially of the elevated plateau. He indicated a few of the localities that would repay special detailed study: Borders of the Lakes of the Clouds; base of the southerly cliff of Mount Monroe; the boggy area above the Fall of the Thousand Streams and the neighborhood of the snow field, both in Tuckerman Ravine; the Alpine Garden; and others. Griggs (1938) indicates further critical stations for future work on plant ecology, especially wind velocity: The "Horn" or "Cape Horn," 4,100 feet; at Mile-post 6 of the Carriage road, 5,340 feet; at the "Cow Pasture," Mile-post 7, 5,850 feet; and on the west side of the mountain near Jacob's Ladder, 4,500 feet. The second and third of Grigg's stations are virtually identical with what the older entomologists called "Semidea Plateau," from the unusual abundance of the White Mountain Butterfly, — the northern end of the Alpine Garden, between the 6- and 7-mile posts, just west of Nelson Crag. The entire area from the Lakes of the

Clouds northward, including Bigelow Lawn and the Alpine Garden, above the head walls of Tuckerman and Huntington Ravines, to the Carriage road at the 6-mile post, a total distance of nearly three miles, should receive special detailed attention from entomologists since it includes almost all of the ecological features peculiar to the alpine area. The higher mountain lakes, especially the Lakes of the Clouds and Star Lake, will well repay detailed systematic collecting.

The author of this paper, with the entomological staff of the Massachusetts State College, has begun the work of gathering the mass of data that has accumulated concerning the insect fauna of the Presidential Range, particularly of the alpine region. The ultimate aim of such a compilation would be the publication of a report, with authentic records and detailed stations, comparable to the remarkably fine list for Mount Desert island, Maine (Procter, 1938). This latter may well be taken as a model for future lists of restricted areas. Dr. Procter divided the island into 39 distinct sections, with more than 300 individual stations and dates of capture; the total list for the island to the date of publication totalled 5,352 species of insects, with 113 additional Arachnida, or virtually double the known species from the higher altitudes of the Mount Washington area. As indicated before, the chief published lists of insects of the Presidential Range are those of Mrs. Slosson, where approximately 2,000 species of insects are recorded from the alpine zone of Washington. If the Tipulidae may be taken as an example, these lists contain many errors of determination and none of the 38 species in this family recorded as alpine actually belongs to this zone. A project such as discussed herewith can be attempted only with the aid of specialists in the various groups to eliminate the synonyms and *nomina nuda*. The botanists already have their detailed record of the higher plants (Pease, 1924) and this work cannot fail to be of the very greatest help to entomologists seeking to correlate entomophilous plants with their insect visitors. Specialists in various groups of insects, or curators of institutions containing named material from the region under consideration, would aid materially in this proposed work by submitting lists of their records to the the author of this report.

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A Review of the Nearctic Wasps of the Genus Trypoxylon (Hymenoptera: Sphecidae)

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Introduction

This paper is a review of the species of *Trypoxylon* of North America north of Mexico, the single extraregional species treated being *T. xantianum* Saussure from Lower California, which has not been discussed since its description. Forty-five names of species or varieties have been used in combination with *Trypoxylon;* of these one is a homonym, three are erroneously reported from North America, one is wrongly referred to this genus, eighteen are synonyms, and twenty-two are here recognized as separate species. The addition of seven new species brings the present number of Nearctic spcies to twenty-nine.

Richards,[1] in a paper based chiefly on material from the Neotropical Region, included some of the Nearctic species in his keys and species groups and redescribed them, but did not attempt to treat them all. Since he gave an exhaustive discussion of the characters of the subgenera and species groups, that phase of the subject is only briefly treated in the present paper, but keys are included for the separation of the Nearctic species, their distribution, based upon specimens actually examined, is discussed, and descriptions are given supported by illustrations of the apical sternite and gentalia of the male.

As in my other papers, the terminology of structures is essentially as found in R. E. Snodgrass' *Anatomy and Physiology of the Honeybee* (1925) and *Principles of Insect Morphology* (1935). The names for the parts of the male genitalia were kindly furnished by Mr. Snodgrass, who is now preparing for publication a paper on hymenopterous genitalia. While descriptions of all the structures seem unnecessary, some explanation of the "ventral organ" of the female and the parts of the male genitalia may be pertinent.

Ventral organ.—The term "ventral organ" was used by Richards for a structure on the ventral surface of the hind coxa of the female, as he considered that it suggested a sense organ. It is usually like a tubercle, the apex of which has a small cavity, but in some species it appears to be a small, oval, hairy patch. This organ is situated on the inner edge of the ventral surface of the coxa and is found most frequently in species of the subgenus *Trypoxylon*, especially in the group of which *figulus* (Linnaeus) is typical.

Male genitalia.—The base of the genitalia consists of a *basal ring*, which is sometimes called the cardo, and to which are attached the bases of the lateral

[1] The American species of the genus *Trypoxylon*. Trans. Roy. Ent. Soc. London **62**:173-362, 1934.

parts or *parameres*. In the subgenus *Trypargilum* the apex of each paramere (Plate 2) is simple, somewhat cylindrical, and not so strongly modified as in the subgenus *Trypoxylon;* in the latter subgenus many of the species have the apex of the paramere divided into two (dorsal and ventral) lamelliform processes (Plates 3 and 4). (For the paramere Richards used the term stipes and the ventral process he called the squama.) Good differences for the separation of species are usually found in the form of the parameres. The *aedeagus*, or central portion, lies between the parameres and is usually considerably modified; in the group of species related to *spinosum* Cameron it shows better specific differences than do the parameres. The inner pair of structures, the volsellae, are attached close to the inner edge of the bases of the parameres and are ventrad of the aedeagus; only in *johnsoni* Fox is each volsella divided into dorsal and ventral portions (Plate 3, Figure 50). The male genitalia were used by Richards in defining the limits of his species groups and my investigations of the Nearctic species have supported his divisions of the genus. In many cases, however, he did not have sufficient material to permit the use of the genitalia as a possible basis for the separation of species. In the Nearctic species the genitalia exhibit good specific differences, especially when supported by the form of the eighth sternite.

Nesting Habits

The Nearctic species of *Trypoxylon*, in so far as their habits are known, use mud in constructing their nests and provision them with spiders. *T. politum* Say makes long tubes which are placed in parallel rows. Other species use mud to construct cells within abandoned cells of the mud-dauber, *Sceliphron caementarium* (Drury), to close holes in wood or crevices in wood or stone, or for partitions in pithy stems.

Material Studied

The collection of *Trypoxylon* in the United States National Museum has served as a basis for this study. This was supplemented by material from the following institutions and individuals: Academy of Natural Sciences at Philadelphia, American Museum of Natural History, Boston Society of Natural History, Colorado State College, University of Colorado, Cornell University, Emory University, Museum of Comparative Zoology at Harvard College, Illinois Natural History Survey, Iowa Wesleyan College, University of Kansas, University of Minnesota, North Carolina Department of Agriculture, North Carolina State College, North Dakota State College, South Dakota State College, Texas Agricultural Experiment Station, State College of Washington, and Oregon Agricultural College, as well as P. H. Timberlake, George Ferguson, C. D. Michener, and G. E. Bohart.

The types in the Academy of Natural Sciences at Philadelphia were studied, and I wish to express my appreciation of the courtesies extended by Mr. E. T. Cresson, Jr., during my visit to that institution. Through the kindness of Dr. R. H. Beamer, of the University of Kansas, the types of Viereck's species were lent for study.

Genus TRYPOXYLON Latreille

Trypoxylon Latreille, Précis des caractères génériques des insectes, p. 121, 1796; Histoire naturelle générale et particulière des crustacés et insectes, vol. 3, p. 338, 1802.—Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 175, 1934. (Genotype: *Sphex figulus* Linnaeus. First included species.)

The genus *Trypoxylon* may be separated from the other sphecoid genera occurring in the Nearctic Region by the deep emarginations of the inner margins of the eyes and by having only one distinct submarginal cell and one recurrent vein in the fore wing. Head, in facial view, subcircular; inner margins of eyes strongly emarginate, each with a deep sinus which suggests that of some vespoid wasps; frontal keel frequently present; transverse keels sometimes developed above antennal foramina; occipital carina usually forming a complete circle, but sometimes obsolescent behind fossa of proboscis or bending forward to meet the hypostomal carina some distance laterad of middle of head; mandibles curved and usually not toothed, but in a few instances bidentate; dorsal surface of propodeum frequently well defined and the sculpture differing with the species; abdomen somewhat clavate.

KEY TO THE SUBGENERA OF TRYPOXYLON

(These characters are essentially as given by Richards.)

1. Fore wing with costa not produced beyond radial cell; hind wing with the two groups of hamuli usually separated by less than length of apical row. Dorsal edge of orifice of propodeum broad and flattened, at most sloping down somewhat in center. Abdominal sternites 2 to 3, usually 2 to 5, bare, with pubescence only at bases of paired bristles. Male: Eighth sternite produced posteriorly into two long spines. (Confined to America.)..... ..... *Trypargilum* Richards

Fore wing with costa produced beyond radial cell; hind wing with the two groups of hamuli separated by more than length of apical row. Dorsal edge of orifice of propodeum narrow, usually sharp-edged and sometimes projecting in a small lobe at most downcurved, and even then not very broad and flattened. Abdominal sternites 2 to 5 somewhat pubescent, at least with a central patch of pubescence. Male: Eighth sternite sometimes bifurcating posteriorly, but the arms never spinelike. (Cosmopolitan)..... *Trypoxylon* Latreille

LIST OF SPECIES GROUPS AND OF SPECIES

Subgenus *Trypargilum* Richards
- Group POLITUM:
  1. *politum* Say
- Group SPINOSUM:
  2. *spinosum* Cameron
  3. *arizonense* Fox
  4. *californicum* Saussure
  5. *xantianum* Saussure
  6. *texense* Saussure
  7. *johannis* Richards
  8. *clavatum* Say
- Group PUNCTULATUM:
  9. *striatum* Provancher
- Group NITIDUM:
  10. *tridentatum* Packard
  11. *rubrocinctum* Packard
  12. *collinum* F. Smith

Subgenus *Trypoxylon* Latreille
- Group FABRICATOR:
  1. *johnsoni* Fox
  2. *adelphiae*, new species
- Group SCUTATUM:
  3. *carinatum* Say
- Group MARGINATUM:
  4. *punctivertex* Richards
- Group FIGULUS:
  5. *apicale* Fox
  6. *frigidum* F. Smith
  7. *aldrichi*, new species
  8. *pennsylvanicum* Saussure

9. *sculleni*, new species
10. *bidentatum* Fox
11. *regulare* Viereck
12. *backi*, new species
13. *fastigium* Fox

Group RUFIDENS:
14. *richardsi*, new species
15. *bridwelli*, new species.

Group uncertain:
16. *timberlakei*, new species

1. Subgenus TRYPARGILUM Richards

Trypoxylon subgenus *Trypargilum* Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 191, 1934. (Genotype: *Trypoxylon nitidum* F. Smith. By original designation.)

KEY TO THE NEARCTIC SPECIES OF THE SUBGENUS TRYPARGILUM

1. Metapleural keel straight. First abdominal tergite with lateral margins parallel for only a short distance, then widening rather abruptly; apex nearly three times as wide as narrowest portion. Dorsal surface of propodeum sparsely punctate, without carinae. Pubescence of head and thorax black. Male: First abdominal sternite with a well-developed hook; middle femur thickened, with hair dense and long ..... *politum* Say

   Metapleural keel strongly curved. First abdominal tergite with lateral margins more nearly parallel; apex about one and one-half times as wide as narrowest portion. Dorsal surface of propodeum usually carinate. Pubescence of head and thorax silvery white or golden. Male: First abdominal sternite without a hook; middle femur not so modified 2

2. Lateral lobe of metapleuron large and convex, usually testaceous. Inner keel of hind coxa strong, reflexed at apex, where it is distinctly separated from emargination for reception of trochanter. Male: Hind trochanter with a spine..... 3

   Lateral lobe of metapleuron smaller and very slightly convex, only edge hyaline or pale. Inner keel of hind coxa not so strong, at apex contiguous to emargination for reception of trochanter. Male: Hind trochanter without a spine 9

3. Dorsal surface of propodeum rather coarsely and irregularly carinulate..... 4
   Dorsal surface of propodeum finely and transversely carinulate 5

4. Punctures on mesoscutum coarse and separated by about a puncture's width. Base of antenna, apex of clypeus, mandible, pronotum, dorsum of propodeum, tegula, legs (for the most part), and first two abdominal segments reddish. Wings with reddish tints. Male: Tooth on hind trochanter long and spiniform ..... *johannis* Richards

   Punctures on mesoscutum fine and separated by several times a puncture's width. Only first two abdominal segments sometimes, and then obscurely, reddish, hind tarsi creamy white. Wings not reddish. Male: Tooth on hind trochanter short and somewhat lamelliform ..... *clavatum* Say

5. Basal joints of antenna, as well as the tibiae, tarsi, and sometimes femora, reddish. Pubescence strongly golden. Ocellocular line equal to diameter of a lateral ocellus. Mesoscutum with distinct punctures. Clypeal margin of female with two teeth on each side of median emargination; of male, with apical-lateral angles of median projection strongly produced. (Eighth sternite of male with tip of apical process curved laterally.) Apical portion of aedeagus gradually and slightly expanded, about twice as wide as narrowest portion.... *texense* Saussure

   Joints of antenna and legs uniformly dark, or only tarsi pale. Pubescence silvery or with hair on face somewhat golden. Ocellocular line two-thirds or less diameter of a lateral ocellus. Mesoscutum with indistinct punctures. Clypeal margin of female with a single tooth on each side of median emargination; of male, with apical-lateral angles of median projection less produced. Apex of aedeagus more strongly produced laterally..... 6

6. Joints 2 and 3 of mid and hind tarsi yellowish. Punctures on supra-antennal area contiguous. Apical half of aedeagus with sides diverging gradually, width at apex about three times that at narrowest portion. (A Neotropical species occurring only in the southern part of Texas.).....*spinosum* Cameron

Joints of tarsi brownish, with only the apices sometimes slightly reddish. Punctures on upper portion of supra-antennal area subcontiguous, interspaces reticulate. Apical portion of aedeagus more abruptly produced or with apical-lateral angle pointed 7

7. Abdominal tergites obscurely reddish, the red most conspicuous on sides of first and base of second. Male: Tooth on hind coxa short, subtriangular; eighth sternite with apical processes short and their tips strongly expanded; apical portion of aedeagus strongly produced laterally, the lateral process subtriangular. (Lower California) .....*xantianum* Saussure

At least basal three abdominal tergites usually largely or entirely reddish (the red less conspicuous in specimens from Oregon and Washington). Male: Tooth on hind coxa longer, spiniform; eighth sternite with tip of apical process not or very slightly expanded; lateral projection of aedeagus arcuate..... 8

8. Fourth abdominal segment largely reddish. Female: Clypeal margin indistinctly emarginate medially; ocellocular line two-thirds postocellar line. Aedeagus with apical portion strongly arcuate, apical-lateral angle not toothed. (Distribution limited to the southwestern part of California.).....*californicum* Saussure

Fourth abdominal segment not, or very obscurely, reddish. Female: Clypeal margin distinctly emarginate medially; ocellocular line barely half postocellar line. Aedeagus with apical portion weakly arcuate, apical-lateral angle strongly toothed. (Rather widely distributed throughout the Western States.) .....*arizonense* Fox

9. Supra-antennal area weakly convex; punctures fine and subcontinguous. Clypeal margin truncate medially. Fore wing uniformly infumate. Black, with joints 1 (except its base) to 4 of hind tarsus white.....*striatum* Provancher

Supra-antennal area strongly convex; punctures coarse and sometimes contiguous. Clypeal margin emarginate medially. Fore wing with base much paler than apex. Black, with some red on second abdominal segment and frequently also on first; joints of hind tarsus dark or testaceous; some red also on head and thorax in *collinum* F. Smith.....10

10. Dorsal surface of propodeum with rather coarse carinulae which on the basal portion are longitudinal or radiate slightly and on the apex are transverse. Apex of clypeus, base of antenna, the legs, pronotum, and propodeum, as well as two basal segments of abdomen, reddish.....*collinum* F. Smith

Dorsal surface of propodeum with fine transverse carinulae. Red confined to basal abdominal segments.....11

11. Dorsal surface of propodeum depressed, bordered on each side by a low carina which terminates posteriorly in a projection (more strongly developed in the male than in the female). Apical half of clypeus with a low median carina. Punctures on sides of supra-antennal area separated by a puncture's width, interspaces reticulate.....*tridentatum* Packard

Dorsal surface of propodeum not depressed and without projections. Clypeus without a median carina. Punctures on supra-antennal area uniformly contiguous .....*rubrocinctum* Packard

Group POLITUM

Group *politum* Rohwer, Proc. U. S. Nat. Mus., vol. 41, p. 472, 1912.
Group of *T. albitarse* Fabricius, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 191 and 212, 1934.

Richards' group of *albitarse* is essentially the same as Rohwer's group

politum, and since the specific identity of *albitarse* is still in doubt Rohwer's earlier name is retained for the group.

In this group the species are large and black with the wings dark and the hind tarsi white and creamy. The metapleural keel is straight. The clypeus of the male is usually modified, frequently having a median projection and small lateral processes. The first abdominal sternite of the male usually has a hooklike projection. The male genitalia have the parameres simple and nearly spiniform; the volsellae are elongate, with the tips rounded; the aedeagus is rather simple.

1. *Trypoxylon (Trypargilum) politum* Say

Plate 1, Fig. 7; Plate 2, Fig. 26

Trypoxylon politus Say, Boston Journ. Nat. Hist., vol. 1, p. 373, 1837.—Leconte, Writ. Thomas Say, vol. 2, p. 756, 1869.

Trypoxylon politum Packard, Proc. Ent. Soc. Philadelphia, vol. 6, p. 413, 1867.—Rau, Psyche, vol. 32, p. 1, 1925; Trans. Acad. Sci. St. Louis, vol. 25, p. 187, 1926; vol. 25, p. 428, 1928.—Dow, Bull. Brooklyn Ent. Soc., vol. 25, p. 99, 1930.

Trypoxylon neglectum Kohl, Verh. Zool. Bot. Ges. Wien, vol. 33, p. 340, pl. 18, fig. 3, 1883; male. (New synonymy.)

Trypoxylon (Trypargilum) neglectum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 230, 1934.

Trypoxylon politiforme Rohwer, Proc. U. S. Nat. Mus. vol. 47, p. 476, 1912; male, female.—Fattig, Can. Ent., vol. 68, p. 44, 1936. (New synonymy.)

Trypoxylon (Trypargilum) politiforme, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 219, 1934.

Trypoxylon basale Rohwer, Proc. U. S. Nat. Mus., vol. 47, p. 475, 1912; male, female. (New synonymy.)

Trypoxylon albitarse Rau (not Fabricius), Ent. News, vol. 24, p. 401, 1913.—Journ. Animal Behavior, vol. 6, p. 26, 1916.

Trypoxylon (Trypargilum) albitarse Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 218 and 351, 1934.

Since *politum* does not occur in the region from which *albitarse* was described, the synonymizing of politum with *albitarse* is to be questioned until Fabricius' type in the Museum at Lund has been studied. The acceptance of the specimens at Kiel as types of *albitarse* by Richards is not in agreement with my interpretation of the case.

Trypoxylon politum may be distinguished from the other Nearctic representatives of the subgenus by its straight metapleural suture and nonstriate propodeum as well as by its black wings and pubescence. The process on the first sternite readily distinguishes the male from all other species of this region.

Both sexes were described by Richards under the name *albitarse*.

Male.—Eighth sternite with a basal process which is strongly concave in the middle; sides converging to bases of apical processes, which are two-thirds the length of the sternite, taper apically, and diverge slightly. Genitalia: Posterior margin of basal ring truncate; base of aedeagus curved dorsally, apical portion thicker than middle portion, apex subtruncate; paramere simple,

tapering and slightly forcipate, mesal surface with rather short bristles; dorsal surface of volsella with a row of short bristles near mesal margin and a single long bristle at apex.

Types.—Of *politum,* lost; of *neglectum,* in the K. K. Zool. Hof-Cabinet Wien; of *basale* and *politiforme,* in the U. S. National Museum.

Type localities.—Of *politum,* Indiana; of *neglectum,* South Carolina; of *basale,* Utica, Miss.; of *politiforme,* Berwick, La.

Distribution.—From Massachusetts south to Florida and west to Kansas and Texas. I have seen specimens from the following States: Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, Georgia, Florida, Alabama, Mississippi, Kentucky, Tennessee, Ohio, Indiana, Illinois, Iowa, Missouri, Arkansas, Louisiana, Kansas, and Texas. Any record of this species from Mexico is probably referable to *mexicanum* Saussure.

Remarks.—In a long series of males there is considerable variation in the process of the first abdominal sternite.

Accounts on the nesting habits are given by Rau, Dow, and Fattig. The mud nests consist of long contiguous tubes suggestive of the name "pipe organ wasps" which was proposed by Rau.

Group SPINOSUM

Group of *T. spinosum* Cameron, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 191 and 230, 1934.

In this group the metapleuron has at its upper extremity a large, convex lateral lobe which is usually paler than the integument of the metanotum or the rest of the metapleuron. The hind coxa has the inner dorsal keel distinctly separated from the emargination for the reception of the trochanter. The hind trochanter of the male has a spiniform or lamelliform projection. The male genitalia have the simple parameres which are usually found in the subgenus *Trypargilum,* but are more strongly pubescent than in the preceding group; the base of the aedeagus bends dorsally much as in *politum,* but the apex frequently has conspicuous lateral projections; the volsellae are strongly rounded. *T. tridentatum,* which was placed by Richards in this group, has been transferred to the *nitidum* group. The separation of some of the species of this group on external structures is difficult, but the male genitalia show good specific differences, especially the aedeagus.

2. *Trypoxylon (Trypargilum) spinosum* Cameron

Plate 1, Fig. 11; Plate 2, Fig. 38

Trypoxylon spinosum Cameron, Biologia Centrali-Americana. Insecta. Hymenoptera, vol. 2, p. 46, pl. 4, fig. 8, 1889; male, female.

Trypoxylon (Trypargilum) spinosum Richards, Trans. Roy. Ent. Soc., London, vol. 82, p. 242, 1934.

Of the Nearctic species of this group, *spinosum* resembles most closely *arizonense,* from which it differs by its more closely punctured supra-antennal

area as well as by its paler second and third joints of the hind basitarsus. Richards compared *spinosum* with his species *salti*, the two having been previously confused under the former name.

Male.—Eighth sternite with basal margin concave; sides slightly sinuate; apical processes half the length of sternite, process widest at base, then tapering to narrower middle portion, beyond which the apical third is expanded laterally, apex rounded, emargination between processes basally semicircular with sides of apical portion subparallel. Male genitalia: Aedeagus in lateral view thickest at base, basal third tapering strongly and middle third tapering less, apical third abruptly expanded and curved, in dorsal view narrowest at base, basal half nearly uniformly wide, sides of apical half diverging strongly so that the width at the apex is nearly three times that at the base. apical-lateral angle rounded and projecting slightly at the side, apex convex medially; paramere about four-fifths as long as aedeagus, simple and tapering to apex, meso-ventral surface with rather long bristles; volsella very short and wide, dorsal surface with a stripe of bristles.

Type.—According to Richards, "Material described in the Biologia Centrali-Americana, now preserved in London."

Type locality.—Presidio, Mexico.

Distribution.—The species is Neotropical, but extends into Texas.

3. *Trypoxylon (Trypargilum) arizonense* Fox

Plate 1, Fig. 4; Plate 2, Fig. 34

Trypoxylon arizonense Fox, Trans. Amer. Ent. Soc., vol. 18, p. 145, pl. 3, fig. 13, 1891; female.—Mickel, Univ. Nebraska Studies, vol. 17, p. 329, 1917; male.

Trypoxylon (Trypargilum) arizonense Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 240, 1934; female, male.

Trypoxylon rufozonalis Fox, Trans. Amer. Ent. Soc., vol. 18, p. 145, pl. 3, fig. 3, 1891; female. (New synonymy.)

As suggested by Richards, this species may be conspecific with *sonorense* Cameron, 1889.

Trypoxylon arizonense may be distinguished from the other Nearctic species of this group, except *californicum*, by the fine carinulae on the dorsal surface of the propodeum and by the sculpturing between the punctures of the supra-antennal area.

Both sexes were redescribed by Richards.

Male.—Eighth sternite similar to that of *spinosum*, but emargination between apical processes less curved at base and the apex of process narrower. Genitalia differing from those of *spinosum* as follows: Aedeagus in lateral view more strongly curved from base and the apex not so strongly expanded, in dorsal view sides expanding gradually from base to near apex, where it is slightly constricted, apical-lateral angle pointed and projecting strongly; paramere more slender and less curved; volsella narrower and more rounded.

Types.—Of *arizonense* and *rufozonalis*, in the Academy of Natural Sciences, Philadelphia.

Type localities.—Of *arizonense,* Arizona; of *rufozonalis,* Colorado.

Distribution.—Texas, New Mexico, Arizona, Colorado, Utah, California, Oregon, and Washington.

Remarks.—*T. arizonense* exhibits considerable variation in the amount of red on the three basal abdominal segments, which range from almost entirely red (typical) to very obscurely reddish in specimens from Washington. The male genitalia were found to be constant throughout the series.

4. *Trypopoxylon (Trypargilum) californicum* Saussure
Plate 1, Fig. 5; Plate 2, Fig. 33

Trypoxylon californicum Saussure, Novara Expedition, Zoologischer Theil, vol. 2, Hymenoptera, p. 78, 1867; female.

This species may easily be confused with *arizonense,* especially female specimens, although the male genitalia show distinct differences. The more extensive reddish color on the fourth abdominal segment in *californicum* may not separate specimens of these two species at the junction of their ranges. The weaker median emargination of the clypeus and longer ocellocular line distinguish the females of *californicum* from those of *arizonense.* In the males the differences in the genitalia are the most reliable for separating the two species.

Male.—Eighth sternite very similar to that of *spinosum,* but base of emargination between apical processes less rounded (in this respect more as in *arizonense*), apical process three-sevenths the length of sternite, apices of processes diverging more than in *arizonense* or *spinosum.* Genitalia: Parameres very similar to those of *spinosum;* volsellae rounded as in *arizonense,* but slightly larger; aedeagus in lateral view with apex slightly thickened, in dorsal view narrowest at base, sides of basal three-eights subparallel, of middle portion diverging gradually, of apical three-eighths strongly arcuate, apex rounded.

Type.—Not located.

Type locality.—California.

Distribution.—California (Westmoreland, La Jolla, Riverside, and Los Angeles County).

5. *Trypoxylon (Trypargilum) xantianum* Saussure
Plate 1, Fig. 10; Plate 2, Fig. 35

Trypoxylon xantianum Saussure, Novara Expedition, Zoologischer Theil, vol. 2, Hymenoptera, p. 78, 1867; male, female.

This species, of which I have seen only the male, resembles rather closely *spinosum,* but may be separated from that species by its dark tarsi, as well as by the dentition of the median projection of the clypeus (*xantianum* having the median tooth as long as the lateral teeth and separated from them by narrower notches) and by the more deeply sulcate dorsal surface of the propodeum. The male genitalia show very distinct specific differences, the most conspicuous being the wide lateral projections near the apex of the aedeagus.

Male.—Eighth sternites similar to that of *spinosum,* but sides converging more strongly; apical processes shorter, with the tip of each abruptly expanded. Genitalia: Similar to those of *spinosum,* especially the parameres; volsella closer to that of *californicum,* but not so strongly rounded and hairs on dorsal surface shorter; aedeagus with basal third slightly wider than middle third, apical portion with lateral projections subtriangular.

Type.—Not located.

Type locality—Promontory, San Lucas, Lower California.

Distribution.—Lower California.

6. *Trypoxylon (Trypargilum) texense* Saussure

Plate 1, Fig. 6; Plate 2, Fig. 32

Trypoxylon texense Saussure, Novara Expedition, Zoologischer Theil, vol. 2, Hymenoptera, p. 77, 1867; female.—Hartman, Bull. Univ. Texas, vol. 65, p. 57, pl. 4, fig. 23, 1905.—Mickel, Univ. Nebraska Studies, vol. 17, p. 76, 1918.—Rau, Trans. Acad. Sci. St. Louis, vol. 25, p. 441, 1928.

Trypoxylon (Trypargilum) texense Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 233, 1934; female, male.

Trypoxylon sulcus LaMunyon, Proc. Nebraska Assoc. Adv. Sci., March 8, 1877.

Trypoxylon aureolum Rohwer, Ent. News, vol. 20, p. 381, 1909; female, male. (New synonymy.)

Trypoxylon relativum Rohwer, Ent. News, vol. 20, p. 382, 1909; female.

From the other Nearctic species of this group *texense* may be distinguished by its golden pubescence and reddish basal joints of the antenna. The carinulae on the dorsal surface of the propodeum are fine and transverse.

Both sexes were redescribed by Richards.

Male.—Eighth sternite similar to that of *spinosum,* but sides converging more strongly; apical processes two-fifths the length of sternite, apices diverging apically. Genitalia of the general type of *spinosum;* paramere wide at base and tapering to apex, with bristles short, especially on basal half; volsella tapering rather strongly to apex; aedeagus nearly uniformy wide, except the apical sixth expanded less than in the preceding species, widest at apex, which is subtruncate.

Types.—Of *texense,* not located; of *aureolum* and *relativum,* in the U. S. National Museum; of *sulcus,* lost.

Type localities.—Of *texense,* Texas; of *sulcus,* North Platte, Nebr.; of *aureolum,* Lee County, Tex.; of *relativum,* Fedor, Lee County, Tex.

Distribution.—Georgia, Alabama, Mississippi, Arkansas, Louisiana, Texas, Kansas, South Dakota, Colorado, and New Mexico.

Remarks.—There is considerable variation in the amount of red on the basal abdominal segments.

The nesting habits were discussed by Hartman and by Rau, according to whom this wasp uses mud to make cells in old nests of *Sceliphron caementarium* (Drury) as well as in crevices and tunnels in wood.

7. *Trypoxylon (Trypargilum) johannis* Richards
Plate 1, Fig. 8; Plate 2, Fig. 39

Trypoxylon (Trypargilum) johannis Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 238, 1934; male, female.

Trypoxylon collinum F. Smith, Catalogue of Hymenopterous Insects. . . . British Museum, pt. 4, p. 381, 1856; in part.—Packard, Proc. Ent. Soc. Philadelphia, vol. 6, p. 415, 1867; female, male.—Fox, Trans. Amer. Ent. Soc., vol. 18, p. 146, 1891; female, male.

Trypoxylon collinum, with which *johannis* has usually been confused, lacks the large lobe on the metapleuron as well as the spine on the hind trochanter of the male. *T. johannis* is readily distinguished from the other species of this group by the extensive red coloring on the thorax and propodeum and, from all these species except *clavatum*, by the coarse irregular carinulae on the dorsal surface of the propodeum.

Both sexes were described by Richards.

Male.—Eighth sternite similar to that of *spinosum*, but with tip of apical process wider. Genitalia with paramere and volsella like those of *arizonense* Fox; aedeagus modified less than those of any of the preceding species, most similar to those of *texense* but the apex narrower.

Type.—In the British Museum.

Type locality.—St. John's Bluff, Fla.

Distribution.—Florida (throughout much of the State) and Georgia (a single specimen without additional data).

Remarks.—The nest is very similar to that of *clavatum* Say.

8. *Trypoxylon (Trypargilum) clavatum* Say
Plate 1, Fig. 3; Plate 2, Fig. 41

Trypoxylon clavatus Say, Boston Journ. Nat. Hist., vol. 1, p. 374, 1837.—LeConte, Writ. Thomas Say, vol. 2, p. 756, 1859.

Trypoxylon clavatum Packard, Proc. Ent. Soc. Philadelphia, vol. 6, p. 414, 1867; female.—Saussure, Novara Expedition, Zoologischer Theil, vol. 2, Hymenoptera, p. 79, 1867; female, male.—Rau, Journ. Anim. Behavior, vol. 6, p. 41, 1916.—Wasp Studies Afield, p. 135, 1918.—Trans. Acad. Sci. St. Louis, vol. 24, p. 22, 1922; vol. 25, p. 198, 1926; vol. 25, p. 406, 1928.—Ann. Ent. Soc. America, vol. 21, p. 26, 1928.—Ent. News, vol. 42, p. 200, 1931.

Trypoxylon (Trypargilum) clavatum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 237, 350, 1934; female, male.

Trypoxylon quintilis Viereck, Trans. Amer. Ent. Soc., vol. 32, p. 206, 1906; male. (New synonymy.)

Trypoxylon cockerellae Rohwer, Trans. Amer. Ent. Soc., vol. 35, p. 130, 1909; female.

Trypoxylon (Trypargilum) clavatum var. *cockerellae* Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 238, 1934; female.

This is the only species of the *spinosum* group which is so widely distributed throughout the United States east of the Rocky Mountains. *Trypoxylon clavatum* agrees with *johannis* in having the dorsal surface of the propodeum strongly and irregularly carinulate, but lacks the more extensive red markings of that species.

Both sexes were redescribed by Richards.

Male.—Eighth sternite very similar to that of *spinosum,* but tip of apical process not expanded. Genitalia very similar to those of *johannis,* especially the parameres and aedeagus, but the volsella differing the most.

Types.—Of *clavatum,* lost; of *cockerellae,* in the U. S. National Museum; of *quintilis,* in Kansas University.

Type localities.—Of *clavatum,* United States; of *cockerellae,* Boulder, Colo.; of *quintilis,* Douglas County, Kans.

Distribution.—From Connecticut south to Florida and west to Colorado. I have seen specimens from the following States: Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Louisiana, Illinois, Iowa, Missouri, Arkansas, Kansas, Texas, and Colorado, and the Province of Ontario.

Remarks.—Specimens from Colorado and Missouri have the second abdominal segment more strongly reddish than do those from other localities.

Notes on the nesting habits are given by Rau, who reported the species as constructing mud cells within deserted cells of the mud-dauber *Sceliphron caementarium* (Drury).

Group PUNCTULATUM

Group of *T. punctulatum* Taschenberg, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 192 and 244, 1934.

In this group the species are superficially similar to those of the group of which *politum* is typical, being rather large and black with dark wings and whitish tarsi. The metapleural keel is strongly curved. The first abdominal sternite of the male has no process and the aedeagus is more strongly modified than in *politum.*

9. *Trypoxylon (Trypargilum) striatum* Provancher

Plate 1, Fig. 9; Plate 2, Figs. 30, 31

Trypoxylon striatum Provancher, Additions et corrections au volume II de la faune entomologique du Canada traitant des hyménoptères, p. 283, 1888; female.—Harrington, Ottawa Nat., vol. 15, p. 222, 1902.—Richards, Trans. Roy Ent. Soc. London, vol. 82, p. 247, 1934.

Trypoxylon cinereum Cameron, Biologia Centrali-Americana. Insecta. Hymenoptera, vol. 2, p. 40, 1889; male, female. (New synonymy.)

Trypoxylon (Trypargilum) cinereum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 247, 1934; female, male.

Trypoxylon albopilosum Fox, Trans. Amer. Ent. Soc., vol. 18, p. 139, 1891; female.—Peckham and Peckham, Psyche, vol. 7, p. 303, 1895.—Wisconsin Geol. & Nat. Hist. Surv. Bull. no. 2, Sci. Series, no. 1, p. 77-87, 1898.—Rau, Trans. Acad. Sci. St. Louis, vol. 25, p. 199, 1926; vol. 25, p. 423, 1928.—Ent. News, vol. 42, p. 200, 1931.

Trypoxylon albopilosum planoense Rohwer, Ent. News, vol. 20, pp. 380, 1909; female. (New synonymy.)

Richards suggested that *striatum* and *cinereum* might be conspecific, but overlooked the synonymizing of *albopilosum* with *striatum* by Harrington.

Trypoxylon striatum resembles superficially small specimens of *politum*, but is readily distinguished by its strongly curved metapleural suture and entirely pale pubescence as well as by the shape of the first abdominal segment. The male of *striatum* lacks the process on the first sternite.

Both sexes were redescribed by Richards under the name *cinereum*.

Male.—Eighth sternite widest at base, sides of basal half converging strongly; apical processes five-eighths the length of sternite and subparallel, tip of process tapering. Genitalia: Paramere simple, sides of basal portion subparallel but widened on mesal margin about one-fourth the distance from base; apex more slender and slightly forcipate, ventral surface beset with short bristles; aedeagus in lateral view with basal portion bent strongly dorsally and then extending posteriorly, apical two-thirds expanded apically, tip truncate, dorsal-apical angle with a process which in lateral view is shaped somewhat like an anvil, sides in dorsal view subparallel; volsella with side of basal portion rounded, apical portion tapering and with an apical process which has short bristles, dorsal surface with a longitudinal keel from the apical portion of which arise short bristles.

Types.—Of *striatum*, in the Canadian National Collection; of *cinereum*, in the British Museum; of *albopilosum*, in the Academy of Natural Sciences, Philadelphia; of *planoense*, in the U. S. National Museum.

Type localities.—Of *striatum*, Ottawa, Ontario; of *cinereum*, Presidio, Mexico; of *albopilosum*, Pennsylvania; of *planoense*, Plano, Tex.

Distribution.—In the Nearctic region, from Massachusetts south to Florida and west to Texas. I have seen specimens from the following States: Massachusetts, Rhode Island, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, Georgia, Florida, Ohio, Wisconsin, Illinois, Louisiana, Missouri, Kansas, and Texas, and the Province of Ontario. For the Neotropical region Richards gives records south to Argentina.

Remarks.—Notes on the nesting habit of this species, under the name *albopilosum*, are given by Peckham and Peckham, as well as by Rau. According to the former authors, holes in posts were utilized, while Rau found old burrows of mining bees occupied by this wasp.

Group NITIDUM

Group of *T. nitidum* Smith, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 192 and 248, 1934.

In this group the species are smaller than in the preceding groups and are frequently paler with the wings subhyaline to hyaline and the abdominal segments sometimes with paler bands. The hind tarsi are dark or yellowish, never white. The apical margin of the clypeus is usually emarginate. The parameres are simple; the aedeagus is curved, with the apex usually reflexed. In color the species of this group are more as those in the group of which *spinosum* is typical, but the lateral lobe of the metapleuron is smaller and the hind coxa of the male has no projection.

10. *Trypoxylon (Trypargilum) tridentatum* Packard

Plate 1, Fig. 2; Plate 2, Figs. 36, 37

Trypoxylon tridentatum Packard, Proc. Ent. Soc. Philadelphia, vol. 6, p. 417, 1867; female.—Fox, Trans. Amer. Ent. Soc., vol. 18, p. 144, 1891; female, male.—Rau, Wasp Studies Afield, p. 134, 1918.—Blackman and Stage, Tech. Publ. No. 17, New York Coll. Forestry, Syracuse Univ., vol. 24, no. 22, p. 196, 1924.—Rau, Can. Ent., vol. 66, p. 259, 1934.

Trypoxylon (Trypargilum) tridentatum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 232, 1934; female, male.

Trypoxylon projectum Fox, Trans. Amer. Ent. Soc., vol. 18, p. 141, 1891; female, male. (New synonymy.)

Trypoxylon (Trypargilum) projectum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 231, 1934; female, male.

Richards placed *tridentatum* in the group *spinosum* with the comment that it is close to the group *nitidum*. *T. tridentatum* is here considered to be nearer to *collinum* and *rubrocinctum* than to the species of the group *spinosum*.

This species is readily recognized by the projections on the dorsal surface of the propodeum.

Both sexes were redescribed by Fox and by Richards

Male.—Eighth sternite with sides converging from base to bases of processes, which are half the length of the sternite; processes subparallel, tip of process expanded with apex oblique. Genitalia: Paramere simple, slender and tapering slightly, ventral surface with very short bristles; aedeagus in lateral view with middle portion arcuate dorsally and tip expanded with a hook on dorsal surface, sides in dorsal view subparallel; volsella rounded laterally, dorsal surface with rather short bristles.

Types.—Of *tridentatum*, not located at Philadelphia; of *projectum*, in the Academy of Natural Sciences at Philadelphia.

Type localities.—Of *tridentatum*, New York; of *projectum*, Louisiana.

Distribution.—Connecticut south to Florida and west to California and British Columbia. I have seen specimens from the following States: Connecticut, New York, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Ohio, Illinois, Kansas, Missouri, Louisiana, Texas, New Mexico, Arizona, Utah, Montana, California, Oregon, and Washington, and the Province of British Columbia.

Remarks.—There is considerable variation in the projections on the propodeum and in the amount of red on the basal abdominal segments.

Rau reports a nest in a tunnel in an elder twig.

11. *Trypoxylon (Trypargilum) rubrocinctum* Packard

Plate 1, Fig. 1; Plate 2, Figs. 27, 28

Trypoxylon rubrocinctum Packard, Proc. Ent. Soc. Philadelphia, vol. 6, p. 416, 1867; female.—Peckham and Peckham, Psyche, vol. 7, p. 303, 1895; Wisconsin Geol. and Nat. Hist. Survey, Bull. No. 2, Sci. Series No. 1, p. 78, 1898.—Rau, Trans. Acad. Sci. St. Louis, vol. 24, p. 22, 1922.

Trypoxylon (Trypargilum) rubrocinctum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 274, 1934; male.

This species agrees with *tridentatum* and *collinum* in having a small lobe on the metapleuron and no tooth on the hind trochanter of the male. It may be separated from *tridentatum* by the smooth dorsal surface of the propodeum as well as by the red on the second abdominal segment being confined to the base of the segment. The red markings on *collinum* are much more extensive.

The male was redescribed by Richards. The female is very similar but with the usual sexual differences. The apical margin of the clypeus is more weakly emarginate and the flagellum more weakly clavate with the joints considerably longer.

Male.—Eighth sternite similar to that of *tridentatum,* but more slender; apical processes three-fifths the length of sternite, tip of process very slightly expanded with apical margin oblique; emargination between processes narrow. Genitalia similar to those of *tridentatum,* with the following differences: Base of paramere wider, apical half narrower and more strongly forcipate; aedeagus in lateral view more gradually curved, apex curved and reflexed dorsally but lacking the hook of *tridentatum;* volsella narrower, sides subparallel, apical process one-third the length of volsella.

Type.—In the Academy of Natural Sciences, Philadelphia.

Type locality.—Delaware.

Distribution.—From Quebec south to Georgia and west to Minnesota and Texas. I have seen specimens from the following States: Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, Georgia, Tennessee, Ohio, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Louisiana, and Texas, and the Provinces of Quebec and Ontario.

Remarks.—This species exhibits practically no variation in the red band on the second abdominal segment. The eighth sternite and genitalia of the male differ little from those of *collinum.*

Peckham and Peckham record this wasp as nesting in mortar between bricks as well as in holes in posts, while Rau reared it from stems of elder with *Chrysis (Trichrysis) parvula* Fabricius as a parasite.

12. *Trypoxylon (Trypargilum) collinum* F. Smith

Plate 2, Fig. 29

Trypoxylon collinum F. Smith, Catalogue of Hymenopterous Insects. . . British Museum, pt. 4, p. 381, 1856; female, in part.

Trypoxylon (Trypargilum) collinum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 271, 1934; female.

This species differs from *rubrocinctum* by its strongly carinulate dorsal surface of the propodeum as well as its more extensive red markings. In superficial appearance *collinum* resembles small specimens of *johannis,* from which it is readily distinguished by its small lobes on the metapleuron and the absence of a spine on the hind trochanter of the male.

The female was redescribed by Richards.

Male.—Agreeing with the female, but with the usual sexual differences: Median emargination of clypeus larger; flagellum shorter and more strongly clavate. First joint of flagellum one and one-half times as long as second, which is subequal to third; fourth twice as long as wide; fourth to tenth joints progressively shorter and wider; tenth one and one-half times as wide as long; apical joint as long as fourth and tapering. Second abdominal segment more slender than that of female. Apical half of seventh tergite with a median carina the apex of which extends a little beyond apical margin of tergite. Eighth sternite very similar to that of *rubrocinctum*. Genitalia: Very similar to those of *rubrocinctum*, the most conspicuous difference being in the aedeagus, which in lateral view has the apex a little more strongly reflexed.

Type.—In the British Museum.

Type locality.—St. John's Bluff, Fla.

Distribution.—Florida and Georgia (Okefinokee Swamp).

Remarks.—The eighth sternite and the genitalia of the males of *rubrocinctum* and *collinum* exhibit fewer differences than do those of any other Nearctic species of the genus.

Subgenus TRYPOXYLON Latreille

Trypoxylon Latreille, Précis des caractères génériques des insectes, p. 121, 1796; Histoire naturelle, générale et particulière des crustacés et insectes, vol. 3, p. 338, 1802. —Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 175 and 191, 1934. (Genotype: *Spex figulus* Linnaeus.)

KEY TO THE NEARCTIC SPECIES OF THE SUBGENUS TRYPOXYLON

1. Upper edge of metapleuron projecting into a wide transparent lamella. Sides of propodeum polished. Mandible, apex of clypeus, pronotal lobe, and the legs in part, yellowish 2

   Upper edge of metapleuron black, at most projecting but slightly. Sides of propodeum carinulate or aciculate. Entirely black or with less extensive yellow markings 3

2. Supra-antennal area dull, densely reticulate, and without punctures. Dorsal surface of propodeum only slightly depressed medially. Male: Apical margin of clypeus with a subtruncate and very short median projection; fourth and eighth joints of flagellum slightly expanded apically. Female: Median fifth of apical margin of clypeus slightly produced, apex of projection weakly emarginate; postocellar line nearly three times as long as ocellocular line.... ..... *adelphiae*, new species

   Supra-antennal area shining, weakly reticulate between sparse punctures. Dorsal surface of propodeum with a distinct median sulcus. Male: Apical margin of clypeus with an arcuate median projection on each side of which is a small rounded tooth; fourth and eighth joints of flagellum strongly expanded apically. Female: Median third of apical margin of clypeus strongly produced, apex of projection truncate; postocellar line less than twice as long as ocellocular line ..... *johnsoni* Fox

3. Frontal carina bifurcate above. Apical margin of clypeus uniformly convex..... 4

   Frontal carina not bifurcate above. Apical margin of clypeus either thickened or with a median projection 5

4. Frontal carina bifurcate below as well as above, portion between antennae not sulcate. Portion of supra-antennal area between arms of carina concave. Mesoscutum and mesopleuron shining, punctures coarse and well separated;

pleural suture strongly developed on lower half of pleuron. (A Neotropical species which extends into southern Texas) ..... *punctivertex* Richards

Frontal carina not bifurcate below, portion between antennae sulcate, with long proclinate bristles arising from sulcus. Portion of supra-antennal area between arms of carina convex. Mesoscutum and mesopleuron dull, punctures fine and moderately close; pleural suture not developed. (Rather widely distributed in southeastern and south central portions of the United States.) ..... *carinatum* Say

5. Transverse keel on face with lateral portions extending posteriorly, the posterior portions parallel and the area between them elevated. Apical margin of clypeus thickened, with two small emarginations through each of which passes a digitiform process of the labrum. Metapleural keel curved. Apices of abdominal tergites 1 to 3 constricted. Male: Some of the flagellar joints bearing tyloids. Female: Apex of mandible bidentate; hind coxa without a ventral organ 6

Transverse keel on face with lateral portions not extending posteriorly, nor an area of face so elevated. Apical margin of clypeus not thickened and without emarginations through which pass processes of the labrum. Metapleural keel straight. Apices of abdominal tergites 1 to 3 not or slightly constricted. Male: None of the flagellar joints bearing a tyloid. Female: Apex of mandible bidentate only in *timberlakei;* hind coxa usually with a ventral organ..... 7

6. Male: Flagellum somewhat clavate; joints 5 to 8 slightly expanded apically and each with a tyloid near apex, appearing moniliform; joint 9 uniformly wide; apical joint tapering gradually to apex, nearly twice as long as preceding joint. Female unknown. (Southern Texas.)..... *bridwelli,* new species

Male: Flagellum very slightly clavate; joints 3 to 9 uniformly wide, each with a low tyloid on basal portion; apical joint tapering abruptly, subequal in length to preceding joint. Female with sculpture similar to that of male. (Rather widely distributed in the Eastern States.)..... *richardsi,* new species

7. Occipital carina meeting hypostomal carina laterad of mid-line of head. Apex of mandible bidentate in female (male unknown). Face with transverse keel obsolescent. First abdominal segment sessile, sides diverging from base; median furrow on first tergite short and shallow. (Southern part of California.) ..... *timberlakei,* new species

Occipital carina forming a complete circle caudad of hypostomal carina. Apex of mandible not bidentate. Face with transverse keel distinct. First abdominal segment petiolate, sides parallel to spiracle or beyond; median furrow on first tergite long and deep 8

8. Supra-antennal area rather strongly convex, without a median prominence; frontal keel very low, appearing more like a polished streak 9

Supra-antennal area either weakly or not convex, without a median prominence; frontal keel well developed 11

9. First abdominal tergite with its sides parallel for about half its length; width at base less than half that at apex. Female: Diameter of a lateral ocellus subequal to postocellar line. (Western States) ..... *bidentatum* Fox

First abdominal tergite with sides divergent from spiracles; width of tergite at base two-thirds that at apex. Female: Diameter of a lateral ocellus only slightly more than half the postocellar line. (Southeastern or south central part of United States) 10

10. Flagellum strongly clavate. Apical margin of clypeus with a strong median projection, which in the female is bidentate and in the male unidentate. Dorsal surface of propodeum bordered laterally by a shallow furrow; carinulae on apical two-thirds transverse. (Maryland to North Carolina) ..... *backi,* new species

Flagellum weakly clavate. Apical margin of clypeus with a weak median pro-

jection which is subtruncate. Dorsal surface of propodeum not bordered laterally by a furrow; carinulae irregular. (Missouri, Kansas) .....*regulare* Viereck

11. Mesonotum and mesopleuron shiny; punctures coarse and separated by at least twice a puncture's width. Dorsal surface of propodeum bordered by a shallow furrow. First abdominal tergite ırly uniformly wide.....*fastigium* Fox

Mesonotum and mesopleuron dull, microscopically aciculate; punctures fine and separated by about a puncture's width. Dorsal surface of propodeum not bordered by a furrow. First abdominal tergite expandned apically.....12

12. Supra-antennal keel weakly developed and on a low prominence 13

Supra-antennal keel strongly developed and on a high prominence 14

13. Supra-antennal area uniformly granular. Hair on mesopleuron and on sides of propodeum short. Male: Apical joint of flagellum twice as long as preceding joint. .....*frigidum* F. Smith

Supra-antennal area granular between shallow punctures. Hairs on mesopleuron unusually long with tips bent posteriorly, hairs on side of propodeum rather long. Male: Apical joint of flagellum four times as long as preceding joint .....*apicale* Fox

14. First abdominal tergite with sides divergent from spiracles. Male: Apical joint of flagellum twice as long as preceding joint, apex tapering abruptly. Female: Area adjacent to ventral organ of hind coxa flattened and reddish..... .....*aldrichi*, new species

First abdominal tergite with sides parallel for some distance beyond spiracles. Male: Apical joint of flagellum at least three times as long as preceding joint, apex tapering slightly. Female: Area adjacent to ventral organ of hind coxa neither flattened nor reddish 15

15. Middle of supra-antennal area granular between shallow punctures; transverse keel uniformly high. First abdominal tergite four times as long as wide at base, basal half with sides subparallel; second tergite two-thirds as long as first. Male: Apical joint of flagellum three times as long as preceding joint .....*sculleni*, new species

Middle of supra-antennal area uniformly granular; transverse keel lower medially. First abdominal tergite nearly six times as long as wide at base, basal two-thirds with sides parallel; second tergite half as long as first. Male: Apical joint of flagellum four times as long as preceding joint..... .....*pennsylvanicum* Saussure

Group FABRICATOR

Group of *T. fabricator* Smith, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 192 and 280, 1934.

This is the only species group of the subgenus *Trypoxylon* occurring in the Nearctic Region which has the upper edge of the metapleuron projecting into a transparent lamella. The apical margin of the clypeus is thin, pale, and often has a median projection. The male genitalia have each paramere divided into two (dorsal and ventral) wide lamelliform processes; each volsella is divided into dorsal and ventral portions (Plate 3, Figure 50).

1. *Trypoxylon (Trypoxylon) johnsoni* Fox

Plate 1, Fig. 21; Plate 3, Figs. 48, 49, 50

Trypoxylon johnsoni Fox, Trans. Amer. Ent. Soc., vol. 18, p. 147, 1891; female.—Rau, Wasp Studies Afield, p. 137, 1918.

Trypoxylon (Trypoxylon) johnsoni Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 293, 1934; female.

Trypoxylon ornatipes Fox, Trans. Amer. Ent. Soc., vol. 18, p. 148, 1891; male. (New synonymy.)

Trypoxylon (Trypoxylon) ornatipes Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 297, 1934; male.

Fox suggested that *ornatipes* was conspecific with *johnsoni*, an opinion with which I concur.

The transparent upper edge of the metapleuron separates *johnsoni* and *adelphiae* from the other Nearctic species of this subgenus. The differences between *johnsoni* and *adelphiae* will be discussed under the latter.

Both sexes were redescribed by Richards, the male under the name *ornatipes*.

Male.—Eighth sternite with basal margin nearly truncate, basal-lateral angle projecting laterally, sides of basal two-thirds converging, of apical third subparallel, apical margin arcuate, each apical-lateral angle with a short tooth, an oval patch of long hair between the teeth. Genitalia: Parmere with apical margin of dorsal process with a few coarse bristles, base of ventral process with a whorl of long bristles; volsella with a ventral portion which is slender and tapering, and a dorsal portion which is slightly longer with its apex pointed and bent laterally; aedeagus with middle third narrowest, tip curved ventrally with two pointed processes which bend laterally, ventral surface basad of processes with a semicircular emargination.

Types.—Of *johnsoni*, in the U. S. National Museum; of *ornatipes*, in the Academy of Natural Sciences, Philadelphia.

Type localities.—Of *johnsoni*, Florida; of *ornatipes*, District of Columbia.

Distribution.—New York, Pennsylvania, New Jersey, District of Columbia, Virginia, North Carolina, Florida, Illinois, and Missouri. Recorded from Texas by Fox.

Remarks.—Rau reported this wasp as nesting in soft wood. This is in agreement with data on specimens I have seen.

2. **Trypoxylon (Trypoxylon) adelphiae** sp. nov.

This species agrees with *johnsoni* in the shape of the clypeus and in having the mandible, the apex of the clypeus, the tegula, and the legs yellowish. It differs from *johnsoni* in having the apical margin of the clypeus less strongly produced in the middle, the dorsal surface of the propodeum with coarser carinulae and lacking a median sulcus, and the supra-antennal area impunctate and more densely granular. The fourth and eighth flagellar joints of the male are not so strongly modified as those of *johnsoni*.

Male.—Length 6 mm. Black, with the following exceptions: Mandible (except tip), apex of clypeus, tegula, fore and middle legs (except trochanters), and base of hind tibia and of hind basitarsus testaceous, rest of legs rufo-fuscous; flagellum rufo-fuscous, paler beneath; abdominal tergites weakly iridescent. Wings hyaline and strongly iridescent; veins fusco-testaceous. Pubescence silvery white.

Head similar to that of *johnsoni*. Distance between eyes at base of clypeus

half that at anterior ocellus. Supra-antennal area strongly convex and densely reticulate; a low median keel or carina extending from the antennal foramina about half way to anterior ocellus and above this keel a shallow median furrow extending to the ocellus. Face laterad of convexity flat and indistinctly sculptured. Postocellar line twice ocellocular line. Vertex slightly convex and reticulate. Occiput indistinctly sculptured. Transverse keels of antennal scrobes arched upward from middle of front and extending to upper part of antennal foramina. Space between foramina equal to distance between a foramen and eye. Antenna: Scape one and one-half times as long as pedicel; flagellum rather strongly clavate, first joint nearly one and one-half times as long as wide, joints distad progressively shorter and wider to tenth, which is twice as wide as long, apex of fourth with a projection on under surface, eighth abruptly expanded to apex, apical joint tapering to apex and as long as the combined lengths of joints 8 to 10. Apical margin of clypeus with a median projection which has a shallow emargination on each side of a wide arcuate portion. Labrum bilobed, the lobes lying in furrows on inner surface of clypeus.

Pronotum with a shallow transverse furrow. Mesoscutum shining, weakly reticulate between punctures, which are separated by two to three times a puncture's width. Mesoscutellum and metanotum with finer and sparser punctures. Mesopleuron shining, indistinctly punctate and reticulate; prepectal suture strongly foveolate. Metapleuron polished, with a wide transparent lamella. Dorsal surface of propodeum slightly depressed in the middle, carinulae on basal portion rather strong and radiating slightly, those on apical portion finer and nearly transverse; posterior surface with a deep median furrow; lateral surface shining and weakly striate.

Abdominal tergites: First twice as long as width at apex, which is twice that at base, with a shallow median furrow on basal fifth; second two-thirds as long as first, its width at base three-fourths that at apex; third and fourth each subequal to length of second. Sternites: Basal margin of seventh with a deep subtriangular emargination, postero-median portion beset with coarse bristles, apical margin truncate in the middle; basal margin of eighth with a shallow emargination, sides of basal three-fourths converging apically but subparallel on apical fourth, apex truncate with a short fimbria, apical-lateral angle with two long bristles. Genitalia similar to those of *johnsoni* Fox, but apex of paramere much narrower. (Genitalia lost in mounting.)

Female.—Length 7 mm. Agreeing with the male in general structures and sculpture, but with the usual sexual differences. Postocellar line nearly three times ocellocular line. Apical margin of clypeus with median fifth slightly produced and projection weakly emarginate. First abdominal tergite twice as long as wide at apex; second tergite five-sevenths as long as first.

Type.—Holotype, U. S. N. M. No. 53426. Allotype in the Museum of Comparative Zoölogy at Harvard College.

Type locality.—"Cedar Glade Area, middle Tenn."

Distribution.—Holotype male taken July 5 by Adelphia Meyer, and allotype female taken at Great Falls, Va., June 25 by Nathan Banks.

Group SCUTATUM

Group of *T. scutatum* Chevrier, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 192 and 337, 1934.

In this group the frontal keel is bifurcate above and the portion between the antennal foramina is sulcate with long proclinate bristles arising from the sulcus. The hind coxa of the female has a ventral organ. The male genitalia have the dorsal and ventral processes of the paramere broad and lamelliform, much as in the group immediately preceding.

3. *Trypoxylon (Trypoxylon) carinatum* Say

Plate 1, Fig. 23; Plate 3, Figs. 44, 45

Trypoxylon carinatus Say, Boston Journ. Nat. Hist., vol. 1, p. 374, 1837; male.—LeConte, Writ. Thomas Say, vol. 2, p. 757, 1859.

Trypoxylon carinatum Fox, Trans. Amer. Ent. Soc., vol. 18, p. 147, 1891; male.—Proc. Acad. Nat. Sci. Philadelphia, p. 475, 1893; female, male.

Trypoxylon (Trypoxylon) carinatum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 329, 1934.—Ann. Mag. Nat. Hist., vol. 18, p. 463, 1936.

This species has the bifurcate frontal carina with long bristles between the antennal foramina as does *scutatum* Chevrier; in this respect it differs from all other Nearctic species.

Male.—Length 8 mm. Black with the following exceptions: Apical margin of clypeus and the mandible rufous; flagellum and legs (for the most part) fusco-piceous; fore tibia and tarsus, basal half of middle basitarsus, calcaria, prothoracic lobe, and mesosternum pale yellow; tegula testaceous; abdominal tergites weakly iridescent. Wings weakly infumate and iridescent; veins fuscous. Pubescence silvery white.

Distance between eyes at base of clypeus five-eighths that at anterior ocellus. Face below arms of carina indistinctly punctured and densely pubescent; area above carina reticulate between shallow punctures, which are separated by at least a puncture's width, pubescence much shorter and sparser than on the lower part. Supra-antennal area strongly elevated in the middle; a median carina extends upward for a short distance, then bifurcates with each arm curving up toward the upper edge of the sinus of the eye and becoming obsolescent before reaching the margin of the eye. A transverse keel extends from the median keel to the tops of the antennal foramina. Space between antennal foramina strongly elevated in the middle, with a median sulcus from which arise several long proclinate bristles. Scape twice as long as pedicel. Flagellum weakly clavate; first and second joints subequal in length; second with a small tyloid near base; third three-fourths as long as second, under surface with a polished paler stripe; apex of third and base of fourth constricted; fourth one and one-half times as long as third, under surface with a basal pale stripe which tapers apically; joints 5 to 10 progressively shorter and wider, the tenth twice as wide as long; apical joint twice as long as tenth and tapering to apex. Vertex more sparsely punctate and reticulate than supra-antennal area; postocellar line twice ocellocular line. Clypeus with a wide, impunctate, subapical band; apical margin with a low, arcuate, median projection which is one-fourth width of margin.

Sculpture of mesonotum similar to that on vertex; mesopleuron less distinctly punctate and reticulate. Metapleuron polished, lamella small and dark. Dorsal surface of propodeum bordered laterally and posteriorly by a shallow furrow, middle third slightly depressed, carinulae on base longitudinal at sides and arcuate medially, those on apex transverse; sides of propodeum polished and weakly striate; posterior surface transversely carinulate, with a deep median sulcus.

Abdominal tergites: Width of first at base two-thirds that at apex and one-third the length; second nearly as long as first, width at base three-fourths that at apex. Eighth sternite with basal margin triangularly emarginate; sides of basal two-thirds converging, of apical third subparallel; apical margin arcuately concave and fimbriate; apical-lateral angle projecting posteriorly. Genitalia: Apical portions of paramere broad and lamelliform (similar to *johnsoni*), mesal margin of dorsal lamella with rather fine and close bristles, ventral surface of ventral lamella rather sparsely beset with bristles the tips of which are curved; volsella in ventral view slender with sides subparallel, apex of dorsal portion beset with short bristles; aedeagus short, slender and nearly uniform, tip slightly curved ventrally, a small ventral process about one-fourth the distance from apex to base.

Female.—Similar to the male, except the usual sexual differences. Flagellum slender, slightly wider at apex. Apical margin of clypeus arcuate, impunctate band wider than in male. Width of first tergite at base half that at apex and one-fourth the length; second three-fourths as long as first. Fore and middle legs darker than those of male.

Type.—Lost.

Type locality.—Indiana.

Distribution.—New York (Long Island), New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, North Carolina, Georgia, Indiana, Missouri, Kansas, and Texas.

Remarks.—Specimens of *carinatum* from Kansas and Texas have the abdominal tergites somewhat rufous, some having the second and third tergites almost banded with red.

Four males of this species were reared from a tunnel in a partially decayed trunk of a tulip tree.

Group MARGINATUM

Group of *T. marginatum* Cameron, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 192 and 329, 1934.

In this group the frontal keel is bifurcate both above and below, but is not sulcate and has no proclinate bristles; the upper arms of the keel frequently enclose a somewhat cordiform area. The pleural suture is strongly developed on the lower half of the mesopleuron. The male genitalia have the aedeagus short and curved, with a ventral hooked process; the paramere is simple, somewhat spatulate and slightly curved; the apex of the volsella is broadly truncate.

4. *Trypoxylon (Trypoxylon) punctivertex* Richards
Plate 1, Fig. 14; Plate 4, Figs. 70, 71

Trypoxylon (Trypoxylon) punctivertex Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 333, 1934; female.

This species has bifurcate arms of the frontal carina as does *carinatum*, but lacks the long bristles in the sulcus between the antennal foramina.

Male.—A male, on the basis of its occurrence in the same region with female specimens, is tentatively placed here. It agrees in general structures with the female, but differs in being smaller (7 mm. long) with a more slender abdomen and less strongly punctured supra-antennal area.

Supra-antennal area with portion between upper arms of frontal carina neither so strongly concave nor so coarsely punctured as in the female. Lower arms of frontal carina extending down toward base of clypeus and then laterally nearly to inner margins of eyes. Postocellar line four times as long as ocellocular line. Clypeus with a low median carina. Antennae gone from the single male seen. Punctures on mesoscutum and mesopleuron somewhat finer and closer than in the female. Sculpture of propodeum as in female. Abdomen slender and slightly clavate; first tergite at apex nearly twice as wide as at base, twice as long as second tergite, which is subequal in length to third. Eighth sternite with basal-lateral angles projecting strongly basally; basal margin arcuate medially; sides of basal three-fifths converging, of apical portion subparallel; apex subsemicircular, with a median triangular projection; hair on apical portion long and projecting beyond apical margin, a tuft of longer hairs at each side. Genitalia: Paramere with basal half wide and mesal portion with long bristles, apical half lamelliform and slightly curved, apical and mesal margins with long bristles; volsella in ventral view with sides subparallel and apex truncate, apex of dorsal portion with long hairs; aedeagus scarcely two-thirds as long as paramere and slender, in lateral view slightly curved, tip wider than portion basad, with a barb-like process on ventral surface.

Type.—In the British Museum; paratype in the U. S. National Museum.

Type locality.—British Guiana; paratype, Panama.

Distribution.—(In the United States) Brownsville and Victoria, Tex.

Group FIGULUS

Group of *T. figulus* Linnaeus, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 193 and 314, 1934.

In this group the species are characterized rather by their lack of the modifications which are found in the other groups of the subgenus *Trypoxylon*. The apical margin of the clypeus usually has a median projection which is sometimes weakly emarginate. The hind coxa of the female has a ventral organ. The male genitalia have the paramere with dorsal and ventral apical processes which are rather narrow and the margin of the dorsal process bears long bristles; the aedeagus is usually curved and frequently has two ventral processes which, in some species, bend laterally; the volsella usually tapers strongly.

5. *Trypoxylon (Trypoxylon) apicale* Fox
Plate 1, Fig. 12; Plate 3, Figs. 61, 64

Trypoxylon apicalis Fox, Trans. Amer. Ent. Soc., vol. 18, p. 142, 1891; female.

Trypoxylon apicale is with difficulty separated from the Palearctic species *figulus*. It can be separated from the other Nearctic species of this group by the hairs on the mesopleuron being long with their tips bent posteriorly, as well as by the dorsal surface of the propodeum.

Female.—Length 10 to 11 mm. Black, with the following exceptions: Mandible reddish; tarsal joints (especially their apices) and sides of first and second abdominal tergites obscurely reddish. Wings yellowish infumate and iridescent, apex of fore wing slightly darker; veins and tegula fusco-testaceous. Pubescence silvery white with some infuscation on upper part of face, on mesoscutum, and on basal portions of abdominal segments.

Head in facial view subcircular, distance from anterior ocellus to apical margin of clypeus subequal to that between emarginations of eyes. Eyes converging slightly below. Supra-antennal area convex, finely tessalate, with fine and rather shallow punctures which are separated by about a puncture's width; frontal suture shallow but distinct from median keel to anterior ocellus. Supra-antennal keel low and on a low prominence. Transverse keel low, nearly straight, but lateral portions slightly curved above antennal foramina. Post-ocellar line subequal to width of an ocellus and twice ocellocular line. Punctures on vertex separated by three to four times a puncture's width. Flagellum of nearly uniform width; relative lengths of joints 1 and 10, 2 to 6, and 7 to 9 as 5: 4: 3; apical joint tapering to apex. Supraclypeal area (true frons) triangular, width of base twice the median height; punctures separated by about a puncture's width; pubescence proclinate. Clypeus slightly convex with punctures of two sizes (small punctures, similar to those on frons, from which arises similar pubescence, and larger shallow punctures which are irregularly scattered and from which arise coarse proclinate bristles); subapical impunctate band slightly depressed; apical margin convex, middle fourth produced, the projection with a weak median emargination and appearing slightly bidentate. Postgena separated from eye by a shallow furrow, declivous from eye to occipital carina. Apex of mandible tapering.

Prothorax with transverse suture narrower medially. Punctures of mesoscutum and scutellum finer than those on vertex, separated by about a puncture's width, interspaces shiny and finely tessellate, mesopleuron shiny, punctures much sparser than those on scutum; prepectal suture foveolate; hairs unusually long and slightly reclinate, with their tips bent posteriorly. Metanotum shiny, slightly convex, punctures finer and closer than those on scutum. Metapleuron polished. Dorsal surface of propodeum not defined by a suture, carinulae on sides longitudinal, middle portion basally with weak transverse carinulae and apically slightly depressed; lateral surface shiny, with very fine and nearly horizontal carinulae. Ventral organ of hind coxa oval, about half way between base and apex of coxa.

Abdominal tergites shiny, indistinctly punctured; width of first tergite at spiracles half that at apex, sides parallel for nearly half length of tergite,

median furrow also half its length; second tergite four-sevenths as long as first, width at base three-fourths that at apex.

Male.—Length 10 mm. In color and general structures agreeing with female, but with the usual sexual differences.

Flagellum slightly clavate; first joint twice as long as wide; joints 2 to 10 progressively shorter and wider, tenth nearly twice as wide as long; apical joint nearly one and one-half times as long as first, tapering to apex. Median projection of clypeal margin not so strongly produced as in female.

First abdominal tergite with length four times, and width at apex twice, the width at base; second tergite five-eighths as long as first. Eighth sternite with basal-lateral angles projecting strongly laterally; width at base nearly twice length; apical third with sides subparallel; apical margin very weakly concave. Genitalia: Paramere wide at base and abruptly narrowed along mesal margin for half its length, apical half consisting of two lamelliform processes, ventral process the longer, sides subparallel to tip, which tapers, dorsal process shorter, basal half narrow and apical half claviform in outline, margins with long bristles which on the mesal margin are strongly curved; volsella with apex tapering strongly, in lateral view subtriangular; aedeagus in dorsal view widest at base, middle portion narrower and apical portion expanded, about one-sixth the distance from apex to base a subtriangular projection of the lateral margin, tip narrow, ventral surface with two short processes which bend laterally.

Type.—In the Academy of Natural Sciences, Philadelphia.

Type locality.—Canada.

Distribution.—Quebec, Maine, New Hampshire, and Massachusetts.

6. *Trypoxylon (Trypoxylon) frigidum* F. Smith

Plate 1, Fig. 19; Plate 3, Figs. 54, 63

Trypoxylon frigidum F. Smith, Catalogue of Hymenopterous Insects. . . British Museum, pt. 4, p. 381, 1856; female.—Packard, Proc. Ent. Soc. Philadelphia, vol. 6, p. 415, 1867; male, female.—Fox, Trans. Amer. Ent. Soc., vol. 18, p. 143, 1891; female only.—Rohwer, Ent. News, vol. 20, p. 377, 1909; female.—?Blackman and Stage, Tech. Publ. No. 17, New York College Forest., Syracuse Univ., vol. 24, No. 22, p. 197, 1924.—Richards, Ann. Mag. Nat. Hist., ser. 10, vol. 18, p. 463, 1936.—?Pate, Bull. Brooklyn Ent Soc., vol. 22, p. 5, 1937.

Trypoxylon (Trypoxylon) frigidum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 318, 1934; female, ?male.

Trypoxylon plesium Rohwer, Proc. U. S. Nat. Mus., vol. 57, p. 229, 1920; female.—Rau, Trans. Acad. Sci. St Louis, vol. 25, p 197, 1926; vol. 25, p. 439, 1928. (New synonymy.)

Trypoxylon (Trypoxylon) plesium Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 319, 1934; female.

This species is similar to *apicale*, from which it differs as follows: Length slightly less, 8 to 9 mm.; supra-antennal area indistinctly punctured, frontal suture less distinct; supra-antennal keel low and on a narrower prominence; median projection of clypeal margin weaker; hair on mesopleuron ordinary; dorsal surface of propodeum not so strongly sulcate medially, carinulae irregular.

Male.—Eighth sternite with sides converging slightly to apex, apical margin concave; apical-lateral angle with a slender apical tooth. Genitalia very similar to those of *apicale* but ventral processes of aedeagus smaller and dorsal process of paramere more slender.

Types.—Of *frigidum,* in the British Museum; of *plesium,* in the U. S. National Museum.

Type localities.—Of *frigidum,* Hudson Bay; of *plesium,* St. Louis, Mo.

Distribution.—From Hudson Bay south to North Carolina and west to Washington and New Mexico. I have seen specimens from the following States: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, North Carolina, Ohio, Michigan, Illinois, Minnesota, Iowa, Missouri, Kansas, Colorado, New Mexico, Montana, and Washington, and the Provinces Alberta, Ontario, and Quebec.

Remarks.—With the exception of *aldrichi,* the males of the other species of this group have the apical joint of the flagellum much longer than in *frigidum.*

Packard reported *frigidum* as living in the stems of *Syringa.*

7. **Trypoxylon (Trypoxylon) aldrichi** sp. nov.

Plate 1, Fig. 25; Plate 3, Figs. 53, 62, 66, 67

In its rather wide first abdominal segment with the sides diverging from the spiracles, or near them, *aldrichi* agrees with *apicale* and *frigidum,* but differs in having a high frontal keel which is on a high prominence, a character found also in *pennsylvanicum* and *sculleni.*

In habitus *aldrichi* is close to *apicale,* from which it differs as follows: Slightly smaller, length of female 9 to 10 mm., of male 8 to 9 mm.; supra-antennal area less granular and punctures less distinct; frontal furrow shallower; frontal keel higher and on a higher prominence; hair on mesopleuron short; dorsal surface of propodeum not sulcate medially, without transverse carinae.

Male.—Supra-antennal area rather weakly granular, punctures indistinct. Frontal furrow shallow. Frontal keel high and on a high and narrow prominence. Ocellocular line five-sevenths as long as postocellar line. Apical margin of clypeus with middle fifth projecting, apex of projection weakly emarginate. Flagellum weakly clavate; first joint twice as long as wide; joints 2 to 4 subequal; fifth joint one and one-half times as long as wide; joints 6 to 10 progressively shorter and wider, one-tenth as wide as long; apical joint twice as long as tenth, tapering to apex. Dorsal surface of propodeum not sulcate medially; carinulae principally longitudinal but diverging slightly. First abdominal tergite with sides diverging from spiracles; second three-fifths as long as first. Basal margin of eighth sternite slightly concave, as wide as length of sternite; sides converging apically; apex slightly less than half as wide as base; apical margin subtruncate; apical-lateral angle with a short apical tooth. Genitalia very similar to those of *frigidum.*

Female.—Agreeing with the male, except for the usual sexual differences. Ocellocular line half as long as postocellar line. Median fourth of clypeal

margin projecting rather strongly, apex of projection subtruncate. Hind coxa with area adjacent to ventral organ flattened and reddish.

Type.—Holotype, allotype, and paratype, U. S. N. M. No. 53427. Paratypes in Washington State College, Oregon Agricultural College, the Canadian National Collection, College of Agriculture, Edmonton, Alberta, and Cornell University, as well as in the private collections of G. E. Bohart, C. D. Michener, and George Ferguson.

Type locality.—Fishtrap Lake, Wash.

Distribution.—Holotype male taken July 8, by J. M. Aldrich. Allotype female taken at Lake Roman, Lake County, Mont., July 6, 1932, by R. D. Eichman. Twenty-seven paratypes from the localities listed below. *Idaho:* One female, Moscow (C. V. Piper); two females, Garwood, August 12, 1911 (M. A. Yothers). *California:* One male, Humboldt County, May 18, 1911 (F. W. Nunenmacher); one male, Cartville, Trinity County, May 17, 1934 (G. E. Bohart); one female, Sequoia National Park, August 22, 1933 (C. D. Michener); one male, Berkeley, April 30, 1937 (G. E. and R. M. Bohart). *Oregon:* One male, Corvallis, June 12, 1924 (H. A. Scullen); one female, Crater Lake, Pole Bridge Meadow, elevation 5,900 feet, August 11, 1935 (George Ferguson); one female, Wildhorse Canyon, Steens Mountains, elevation 4,270 to 6,000 feet, July 5, 1927 (H. A. Scullen); one female, Wallowa Lake, Aneroid Lake Trail, elevation 5,000 to 6,000 feet, July 24, 1929 (H. A. Scullen); one male, Head of Blitzen River, Steens Mountains, elevation 7,000 feet, July 26, 1937 (Bolinger and Jewett). *Alberta:* Two males, Lethbridge, July 28, 1916 (F. W. L. Sladen); two males, Waterton, August 12, 1922 (H. L. Seamans); one female, Waterton, July 12, 1923 (E. H. Strickland). *British Columbia:* Six females, Oliver, May 16, 21, 22, and 28, and June 7 and 8, 1923 (C. B. Garrett); one female, Oliver, July 10, 1923 (E. R. Buckell); one female, Kaslo, August 24, 1907 (J. M. Cockle); one male, Sicamous, May 25, 1918 (W. Downes); one female, Ground Hog Basin, Big Bend County, Selkirk Mountains, July 25, 1905.

Remarks.—The flagellum of the male of *aldrichi* is very like that of *frigidum*, these two species being the only ones of this group to have it so uniform, with the apical joint only twice as long as the preceding joint.

8. *Trypoxylon (Trypoxylon) pennsylvanicum* Saussure

Plate 1, Fig. 20; Plate 3, Figs. 46, 47, 56, 57

Trypoxylon pennsylvanicum Saussure, Novara Expedition, Zoologischer Theil, vol. 2, Hymenoptera, p. 82, 1867; female.

?*Trypoxylon (Trypoxylon) frigidum* Richards (not F. Smith), Trans. Roy. Ent. Soc. London, vol. 82, p. 318, 1934; male only.

Trypoxylon (Trypoxylon) bidentatum Richards (not Fox), Trans. Roy. Ent. Soc. London, vol. 82, p. 316, 1934; female.

Trypoxylon (Trypoxylon) apicale Richards (not Fox), Trans. Roy. Ent. Soc. London, vol. 82, p. 317, 1934; female.

This species has usually been confused with either *frigidum* or *bidentatum*. Any references to *bidentatum* from the Eastern States probably apply to *pennsylvanicum*. In its long and slender first abdominal segment *pennsylvan-*

icum resembles the Palearctic species *attenuatum* F. Smith. *Trypoxylon pennsylvanicum* is easily separated from the other Nearctic species which occur east of the Rocky Mountains by its long and slender first abdominal segment and high frontal keel.

In habitus similar to *apicale*, from which it differs as follows: Supra-antennal area granular and impunctate; frontal keel higher and on a higher prominence; median projection of clypeal margin narrower; hair on mesopleuron short; dorsal surface of propodeum not sulcate medially, carinulae less regular; first abdominal segment much more slender, in the female with sides subparallel and with a median furrow on basal two-thirds, length nearly six times its apical width and twice as long as second tergite.

Male.—Flagellum slightly clavate; first joint slightly shorter than second; joints 2 to 6 subequal in length and progressively slightly wider; joints 7 to 10 progressively shorter and wider, tenth twice as wide as long; apical joint four times as long as tenth. Eighth sternite with basal margin nearly straight; sides converging apically; apical margin concave with lateral angles strongly toothed. Genitalia very similar to those of *frigidum*, but apical processes of paramere narrower and subequal in length and ventral processes of aedeagus smaller.

Type.—Not located.

Type locality.—Pennsylvania.

Distribution.—From Quebec south to North Carolina and west to Colorado. I have seen specimens from the following States: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, North Carolina, Alabama, Louisiana, Michigan, Wisconsin, Illinois, Minnesota, Iowa, Missouri, Texas, North Dakota, and Colorado, and the Provinces of Quebec, and Ontario.

A specimen from Bar Harbor, Maine, was reared from a twig of red oak.

9. **Trypoxylon (Trypoxylon) sculleni** sp. nov.

Plate 1, Fig. 15; Plate 3, Figs. 52, 58, 59, 65

This species agrees with *apicale* in habitus, but differs as follows: Supra-antennal area uniformly granular, impunctate; frontal keel higher and on a higher, narrower prominence; median projection of clypeal margin shorter; hair on mesopleuron short; carinulae on dorsal surface of propodeum laterad of median sulcus diverging more; abdomen more slender. In its high frontal keel and long, slender first abdominal segment *sculleni* is closer to *pennsylvanicum*, from which it differs by its impunctate supra-antennal area, wider median projection of clypeal margin, longer ocellocular line, and more regular carinulae on dorsal surface of propodeum.

Length of male 7 to 8 mm., of female 10 mm. Color as in *apicale*.

Male.—Supra-antennal area weakly convex, uniformly granular and impunctate. Frontal suture distinct from frontal keel to anterior ocellus. Frontal keel high and on a high prominence. Median projection of clypeal margin weakly emarginate. Flagellum slightly clavate; first joint nearly twice

as long as wide and half as wide as tenth; joints 1 and 2 subequal; joints 3 to 5 subequal in length, each one and one-half times as long as first; joints 6 to 10 progressively shorter, tenth as wide as long; apical joint tapering to apex, three times as long as tenth.

Dorsal surface of propodeum with median sulcus shallow; transversely carinulate; carinulae laterad of sulcus radiating slightly, those on apex transverse.

Abdomen slightly clavate; first segment with sides parallel for half its length, which is four times the width at base, apex one and one-half times basal width; second segment five-eighths as long as first. Eighth sternite with basal margin nearly straight and about three and one-half times as wide as apex; sides of basal two-thirds converging more strongly than on apical third; apical margin weakly concave, lateral angles very slightly produced posteriorly. Genitalia very similar to those of *frigidum*, but volsella in lateral view narrower.

Female.—Similar to the male, but with the usual sexual differences. Postocellar line slightly longer than ocellocular line. Median fourth of clypeal margin slightly produced, apex of projection subtruncate. Abdomen a little wider than that of male; apex of first tergite twice as wide as base; second tergite two-thirds as long as first.

Type.—Holotype, allotype, and paratype, U. S. N. M. No. 53428. Paratypes in the Canadian National Collection, Oregon Agricultural College, Kansas University, the Museum of Comparative Zoölogy at Harvard College, Washington State College, and Cornell University, as well as in the private collections of P. H. Timberlake, C. D. Michener, and G. E. Bohart.

Type locality.—Corvallis, Oreg.

Distribution.—Holotype male and allotype female taken at the type locality on March 6, 1929, by H. A. Scullen. Thirty-five paratypes from the localities listed below. *Oregon:* Seven males and one female, Corvallis, one male, February 25, 1929, two males, April 11, 1930, one male, April 21, 1930, one male, April 23, 1930, one female, May 9, 1929, one male June 12, 1925, and one male Acc. No. 2798 (H. A. Scullen); three females, Corvallis, July 10 and 20, 1910, September 15, 1907 (J. C. Bridwell); one female, Dixie Mountain, Blue Mountains, elevation 6,000 to 6,700 feet, August 12, 1929 (H. A. Scullen); one female, North Powder, elevation 3,240 feet, August 10, 1929, on *Cleome serrulata* (H. A. Scullen). *California:* One female, Los Angeles; one female, Pasadena, June 26, 1907 (F. Grinnell, Jr.); one female, Mountains near Claremont (C. F. Baker); one female, Claremont (C. F. Baker); one female, Alameda Foothills (W. M. Giffard); one male, Riverside, May 9, 1930, on *Helianthus* (P. H. Timberlake); one female, Berkeley, May 20, 1935 (R. M. Bohart); one female, Eagle Rock Hills, Los Angeles County, "spring" 1934 (C. D. Michener); one female, Carrville, Trinity County, May 16, 1934 (G. E. Bohart); one female, Agnew Meadows, Madera County, July 30, 1936 (G. E. and R. M. Bohart). *Arizona:* One female, Lukachukai Mountains, July 27, 1935 (C. T. Brues). *New Mexico:* One female, Santa Fe, September 19 (T. D. A. Cockerell). *Montana:* One female, without addi-

tional data. *Washington:* One female, Sprague Lake (R. C. Shannon); one male, Conway, July 28, 1931 (M. W. Sanderson); one female, Yakima River, July 4 to 15, 1882; one female, Pullman, September 1, 1911; one female, Yakima, July 19, 1920 (A. Spuler); one male and one female, Almota, March 9, 1934 (J. F. G. Clarke); one female, Walla Walla, June 1926 (G. E. Bohart); *British Columbia:* One male, Secamous, May 25, 1918 (W. Downes).

Remarks.—This species was reared from *Rhus glabra* at Almota, Wash., by J. F. G. Clarke. A twig from which H. A. Scullen reared a part of the type series at Corvallis, Oreg., and which he deposited in the U. S. National Museum contained a central gallery the partitions of which were made of mud; the entrance was made at the pruned end of the twig.

10. *Trypoxylon (Trypoxylon) bidentatum* Fox

Plate 1, Fig. 16; Plate 3, Figs. 51, 51a, 55, 60

Trypoxylon bidentatum Fox, Trans. Amer. Ent. Soc., vol. 18, p. 143, 1891; female, male (? in part).

?*Trypoxylon (Trypoxylon) morrisoni* Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 319, 1934; female. (New synonymy.)

This species agrees with the two following, *regulare* and *backi*, in having the supra-antennal area rather strongly convex, in lacking a median prominence, and in having the frontal keel so reduced that it appears to be a polished streak rather than a keel. In these three species, as well as in *fastigium*, the abdomen is relatively slender. *Trypoxylon bidentatum* differs from *regulare* and *backi* in having the first tergite nearly twice as long as the second, and the median projection of the clypeal margin bidentate in both sexes.

Female.—Of the habitus and color of *apicale*, but smaller and more slender. Length 8 to 9 mm.

Supra-antennal area strongly convex, densely graular between shallow punctures which are separated by nearly twice a puncture's width. Frontal keel very low and not on a median prominence; frontal furrow shallow, especially the lower half. Ocellocular line one-third as long as postocellar line. Middle fifth of apical margin of clypeus produced, apex of projection weakly bidentate.

Punctures on mesoscutum fine and separated by two to three times a puncture's width; interspaces finely tessellate. Mesopleuron with punctures slightly larger, shallower and considerably sparser. Dorsal surface of propodeum medially sulcate and transversely carinulate, portions laterad of sulcus with short longitudinal carinulae on basal portion, beyond which the carinulae are irregularly reticulate; lateral surface of propodeum finely striate. Ventral organ of hind coxa as in the other species of this group.

Abdomen narrowly clavate; first segment nearly twice as long as second, sides of basal half subparallel; apex one and three-fourths times as wide as base.

Male.—Similar to the female, but with the usual sexual differences. Apical margin of clypeus less strongly produced in the middle. Flagellum somewhat clavate; first joint one and one-half times as long as wide; joints 2 to 10

progressively shorter and wider, tenth twice as wide as long; apical joint about six times as long as tenth. Median sulcus of dorsal surface of propodeum shallower than that of female. First abdominal segment slender, base three-fifths as wide as apex; second tergite five-eighths as long as first. Eighth sternite with basal margin slightly convex; width at base one and one-fourth times length, basal angles projecting laterally; sides converging to apex, which is one-fifth as wide as base; apical-lateral angle with a short apical tooth. Genitalia similar to those of *frigidum* and *apicale*, but apical processes of paramere shorter and volsella in lateral view wider.

Types.—Of *bidentatum*, in the Academy of Natural Sciences, Philadelphia; of *morrisoni*, in the British Museum.

Type localities.—Of *bidentatum*, Mount Hood, Oreg.; of *morrisoni*, Nevada.

Distribution.—Arizona, Utah, Idaho, California, Oregon, and Washington. Any record for a locality east of the Rocky Mountains probably should apply to *pennsylvanicum*.

11. *Trypoxylon (Trypoxylon) regulare* Viereck
Plate 1, Fig. 13; Plate 4, Figs. 68, 69

Trypoxylon regularis Viereck, Trans. Amer. Ent. Soc., vol. 32, p. 205, 1906; "female" [but type is a male].

Trypoxylon regulare Rohwer, Ent. News, vol. 20, p. 379, 1909.

The type specimen of *regulare* has been examined and is a male, not a female as stated by Viereck. The data on the labels agree in every detail with those given by Viereck, so there can be little doubt that this specimen was the one upon which Viereck based his description. The abdomen is gone, but so was that of the type when the description was written. The only statement of Viereck's which does not apply to the specimen seen is the description of the antenna; he stated that the joints beyond the fourth were subequal, while they are progressively shorter and wider to the tenth, and the apical joint is considerably longer (as in *bidentatum*). However, Viereck also stated "Joints of the antenna not well separated," so it is possible that he assumed them to be subequal as is the case in the females of related species.

Trypoxylon regulare is distinguished from all the other Nearctic species of this group (except *bidentatum* and *backi*) by its strongly convex supra-antennal area and low frontal keel. The truncate apex of the median projection of the clypeal margin and the more coarsely punctured mesoscutum separate *regulare* from those two species.

Male.—Head and thorax very similar to those of *bidentatum*, but differing as follows: Apex of median projection of clypeal margin subtruncate; punctures on mesoscutum and mesopleuron a little coarser and closer; dorsal surface of propodeum not sulcate medially, carinulae less regular.

The single male on which the following description of the abdomen is based lacks the head, but several females which were reared at the same time have the frontal keel and the projection of the clypeal margin as in *regulare*. Abdomen slender, slightly clavate; width of first segment at apex one and one-

fourth times that at base, sides diverging gradually from base; second tergite two-thirds as long as first. Eighth sternite as wide at base as long; apex seven-tenths as wide as base; sides of basal three-fifths converging apically, of apical portion subparallel; apical margin strongly arcuate, each lateral angle with a slender posterior tooth. Genitalia of the general type of *apicale*, but with the apical processes of paramere more nearly as in *carinatum*, and the bristles on paramere shorter than in *bidentatum;* volsella short and stout; aedeagus without processes; apex strongly downcurved.

Female.—Similar to the male, but with the usual sexual differences. Length 6 to 7 mm. Differing from the female of *bidentatum* as follows: Supra-antennal area less granular, impunctate; frontal furrow shallower. Apex of median projection of clypeal margin truncate. Punctures on mesoscutum and sculpture of dorsal surface of propodeum as in the male.

Type.—In Kansas University.

Type locality.—Douglas County, Kans.

Distribution.—Kansas (type locality) and Missouri (St. Louis).

12. **Trypoxylon (Trypoxylon) backi** sp. nov.

Plate 1, Figure 18; Plate 4, Figs. 74, 75

Of the Nearctic species belonging in the group *figulus, backi* agrees with *regulare* and *bidentatum* in having the supra-antennal area strongly convex, with a very low frontal keel which is not on a median prominence. The strongly clavate flagellum, the dentition of the clypeal margin, and the male genitalia, in which *backi* is more like the Palearctic species *clavicerum* Lepeletier, readily separate *backi* from *regulare* and *bidentatum.*

Male.—Length about 7 mm. Black, with the following exceptions: Mandible reddish yellow; flagellum dark brown; legs brown slightly tinged with red, tarsal joints paler. Wings subhyaline, yellowish infumate, iridescent; tegula fusco-testaceous. Pubescence silvery white.

Head in facial view subcircular; distance from anterior ocellus to apical margin of clypeus slightly greater than that between emarginations of eyes. Eyes converging slightly below. Supra-antennal area strongly convex, very finely tessellate, with fine punctures which are separated by a puncture's width. Supra-antennal keel obsolescent. Transverse keel moderately well developed, curved above antennal foramina. Scape at apex nearly as wide as long. Pedicel as wide as long. Flagellum short and strongly clavate; first joint one and one-half times as long as wide; second and third each as wide as long; fourth to tenth progressively shorter and wider, tenth two and one-half times as wide as long; apical joint twice as long as width at base. Punctures on vertex sparser than those on face. Postocellar line slightly longer than the diameter of an ocellus and ocellocular line half as long. Clypeus weakly convex, indistinctly punctured; depressed apical margin narrow, median third produced and a small median tooth on the projection.

Punctures of mesoscutum and scutellum slightly finer than those on face, interspaces shiny and finely tessellate. Mesopleuron shiny, punctures sparser, prepectal suture foveolate. Metanotum shiny, indistinctly punctured; meta-

pleuron polished. Propodeum with dorsal surface defined laterally and posteriorly by a furrow, shiny; base of dorsal area longitudinally and apex transversely carinulate; lateral surfaces finely striate.

Abdominal tergites shining, indistinctly punctured; first with median furrow extending two-fifths its length, width at base slightly more than half that at apex and one-third length, apex slightly constricted (best seen in lateral view), apex of second less constricted and nearly as wide as length of tergite; third wider than long. Eighth sternite widest at base, nearly three times as wide as apex; sides of basal two-thirds converging strongly, of apical third slightly; apical margin truncate, lateral angles not produced. Genitalia: Lamelliform processes of paramere shorter than in *regulare*, mesal and apical margins of dorsal plate beset with coarse bristles; volsella in lateral view broadly subtriangular; aedeagus nearly uniformly wide, apex tapering slightly and downcurved, lacking lateral projections, ventral processes similar to those of *frigidum*.

Female.—Differing from the male chiefly in sexual characters; apical margin of clypeus with median portion more strongly produced and projection medially bidentate; flagellum more weakly clavate; first and second abdominal segments more nearly uniform in width. Ventral organ of hind coxa about one-third the distance from apex.

Type.—Holotype, allotype, and paratypes, U. S. N. M. No. 53429. Paratypes in North Carolina Department of Agriculture and State College, University of North Carolina.

Type locality.—Baltimore, Md.

Distribution.—Holotype male, allotype female, and five male and three female paratypes taken at the type locality by E. A. Back. Thirty-six paratypes from the localities listed below. *Maryland:* One male, Beltsville, June 9 (N. Banks); one female, Berwyn, May 22, 1921 (A. B. Gahan); two females, Takoma Park, July 1, 1932 (E. A. Back). *Virginia:* Four males, Norfolk, July 17, 1934 (H. G. Walker); one female and three males, Falls Church, May 30 (S. A. Rohwer); two males and one female, Falls Church, June 9 and 10 (G. C. Rohwer); five males, Vienna, August 1932 (J. C. Bridwell); one male, Bluemont, September 1929 ("Dr. Miller"). *North Carolina:* One male, North Fork, Swannanoa, Black Mountains, May (N. Banks); one female and one male, Raleigh, July 24, 1931 (T. J. Jones); six males, Raleigh, July 5, 1934 (J. C. Boombour); one female and two males, Morgantown, August 1937; two males and one female without labels, but received from North Carolina.

Remarks.—Labels on some of the specimens indicate that this species nests in wood, sometimes in the burrows of powder-post beetles.

13. *Trypoxylon (Trypoxylon) fastigium* Fox

Plate 1, Fig. 17; Plate 4, Figs. 72, 73

Trypoxylon carinifrons Fox, Trans. Amer. Ent. Soc., vol. 18, p. 136, 1891; female.
Trypoxylon fastigium Fox, Proc. Acad. Nat. Sci. Philadelphia, p. 473, 476, 1893. (Proposed for *Trypoxylon carinifrons* Fox, 1891, not *carinifrons* Cameron 1889.)

Trypoxylon (Trypoxylon) fastigium Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 315, 1934.

Trypoxylon subfrigidum Rohwer, Ent. News, vol. 20, p. 378, 1909; male. (New synonymy.)

Trypoxylon suffrigidum Richards, Ann. Mag. Nat. Hist., vol. 18, p. 463, 1936. (Lapsus for *subfrigidum*.)

Trypoxylon nigrellum Rohwer, Ent. News, vol. 20, p. 379, 1909; female. (New synonymy.)

Trypoxylon (Trypoxylon) nigrellum Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 320, 1934; female.

Trypoxylon fastigium may be separated from the other Nearctic species of this group by its coarsely and sparsely punctured mesoscutum and mesopleuron, and from all except *backi* by its short and nearly uniformly wide first abdominal tergite.

The female was redescribed by Richards under the name of *nigrellum*.

Male.—Similar to the female but with the usual sexual differences. Flagellum more strongly clavate than in female; first joint nearly twice as long as wide; joints 2 to 10 progressively shorter and wider, tenth twice as wide as long; apical joint tapering to apex, length twice width at base. Middle third of apical margin of clypeus strongly produced and weakly bidentate. Abdomen more slender than in the female; first tergite slightly wider at apex, which is one-third the length; second nearly as long as first. Eighth sternite with sides converging slightly from base; apical margin slightly convex, lateral angles each with a short posterior tooth. Genitalia much stouter than those of *apicale;* aedeagus without lateral projections, in lateral view hamate; apical processes of paramere flat and closely appressed, margins lacking bristles, ventral surface of paramere with erect bristles; volsella short and wide, in lateral view broadly rounded, apex with bristles.

Types.—Of *carinifrons*, in the Academy of Natural Sciences, Philadelphia; of *subfrigidum* and *nigrellum*, in the U. S. National Museum.

Type localities.—Of *carinifrons*, Texas; of *subfrigidum*, Fedor, Tex.; of *nigrellum*, Lee County, Tex.

Distribution.—District of Columbia, Georgia, Mississippi, Texas, Kansas, Idaho, and California. The distribution records for this species are very disconnected, but, with the exception of Idaho, a male from each State has been dissected and the genitalia found to be constant. The specimens upon which Brimley (Insects of North Carolina, p. 443, 1938) based the occurrence of *fastigium* in North Carolina were studied and are referable to *backi*.

Group RUFIDENS

Group of *T. rufidens* Cameron, Richards, Trans. Roy. Ent. Soc. London, vol. 82, p. 192 and 325, 1934.

In this group the mandibles are bidentate. The apical margin of the clypeus is thickened medially and two digitiform lobes of the labrum project beyond the margin from deep furrows on the inner surface of the clypeus. The supra-antennal area has a median U-shaped elevated area which is bordered below and at the sides by the posterior arms of the transverse keel.

The metapleural keel is curved. The male genitalia have the parameres simple; the volsella are three-fourths as long as the aedeagus, which is curved and has ventral processes similar to those of the preceding group. The flagellum in the males has some joints with tyloids.

14. **Trypoxylon (Trypoxylon) richardsi** sp. nov.

Plate 1, Fig. 22; Plate 2, Figs. 42, 43

This is the only species of this group which is known to occur in the United States outside of southern Texas.

Since the males of no Neotropical species of this group are available, comparisons with females only are given. The female of *richardsi* differs from that of *rufidens* as follows: Supra-antennal area more closely punctured; thickened portion of clypeal margin in ventral view more uniformly arcuate and wider; carinulae on dorsal surface of propodeum finer; apices of basal abdominal tergites less constricted. The female of *barberi* Richards differs less, but has a thicker clypeal margin and stronger carinae on the lateral surface of the propodeum, as well as paler prothoracic lobe, legs, and apex of clypeus. The differences between the males of *richardsi* and *bridwelli* will be discussed under the latter species.

Male.—Length 5 mm. Black, with the following exceptions: Mandible yellowish, tip rufous; flagellum and legs brownish, but fore and middle tarsi paler. Wings slightly infumate, iridescent; veins dark brown. Pubescence silvery white.

Head in facial view subcircular. Supra-antennal area strongly convex, punctures fine and rather shallow, interspaces granular. Frontal keel and frontal furrow obsolescent. Transverse keel anteriorly lamelliform and extending over bases of antennae, lateral portions bending posteriorly with posterior arms subparallel. Ocelli in an equilateral triangle; postocellar line twice ocellocular line. Apical margin of clypeus greatly thickened; median portion (in ventral view) arcuate and with two semicircular notches through each of which extends a digitiform process of the labrum. Apex of mandible not toothed. Flagellum weakly clavate; first joint as wide as long; second one and one-half times as long as first; joints 3 to 10 subequal in length, 3 to 9 each with a low tyloid on basal portion of joint; apical joint as long as first, tapering strongly to apex.

Mesoscutum with very fine punctures which are separated by about a puncture's width, interspaces finely aciculate; mesoscutellum and mesopleuron more sparsely punctured. Metapleuron polished. Dorsal surface of propodeum with longitudinal carinae which diverge slightly; sides finely carinate.

Abdomen nearly uniformly wide; apical margins of tergites 1 to 3 slightly constricted (best seen in lateral view); sides of first tergite diverging from base, median sulcus wide and shallow, ending opposite spiracles; second tergite as long as first. Eighth sternite nearly uniformly wide; basal margin strongly concave; apical margin strongly arcuate, with an apical fimbria which is half as long as the sternite. Genitalia: Paramere without a process, mesal surface with erect bristles; volsella three-fourths as long as aedeagus, in ventral view

with sides subparallel and apex rounded, apical portion of dorsal surface with long bristles; aedeagus nearly uniformly thick to apex, which is slightly wider and curved ventrally, ventral processes as in *frigidum*.

Female.—Length 6 mm. Differing from the male in the usual sexual characters. Postocellar line twice ocellocular line. Apical margin of clypeus thicker than that of male. Apex of mandible bidentate, upper tooth much shorter than the lower and separated from it by a shallow notch. Apices of basal three abdominal tergites more strongly constricted than those of male.

Type.—Holotype, allotype, and paratypes, U. S. N. M. No. 53430. Paratypes in the Museum of Comparative Zoölogy at Harvard College and in the private collection of Karl V. Krombein.

Type locality.—Chevy Chase, Md.

Distribution.—Holotype male, taken by H. H. Smith. Allotype female, taken at Rosslyn, Va., by H. H. Smith. Twenty-one paratypes from the localities listed below. *Virginia:* One male, Great Falls, June 25 (N. Banks); one male, "Va. in twig gall on oak," June 1883 (T. Pergande); seven males and four females, Falls Church, May 24 and 30, June 2, 6, 12, 18, and 21, July 12, and August 7 (N. Banks). *District of Columbia:* One male, Georgetown (H. H. Smith). *West Virginia:* One female, French Creek, Quaintance No. 21288 (F. E. Brooks). *Pennsylvania:* One male, Carlisle Junction, June 24, 1910 (W. S. Fisher); one female, Mount Holly Springs, July 4, 1918 (R. M. Fouts). *New York:* One female, Millwood, June 21, 1936 (J. G. Franclemont); one male, Bohemia, Long Island, June 20, 1937 (K. V. Krombein). *Alabama:* One female, Langdale, Chambers County (H. H. Smith). *Texas:* One male, Dallas, April 3, 1907 (R. A. Cushman).

15. **Trypoxylon (Trypoxylon) bridwelli** sp. nov.

Plate 1, Fig. 24; Plate 2, Fig. 40

This species is probably Neotropical rather than Nearctic in distribution and may prove to be conspecific with one of the Neotropical species of which only the female is known.

Male.—Length 4 mm. Similar to the male of *richardsi*, from which it differs as follows: Supra-antennal area less granular and punctures shallower; thickened median portion of clypeal margin thicker and shorter; flagellum more strongly clavate, with ninth joint more strongly modified and apical joint larger; punctures on mesosotum a little closer; eighth sternite with basal margin more regularly arcuate and hairs at lateral extremities of apical fimbria much longer; genitalia with volsella and apex of paramere narrower. Joints 1 and 2 of flagellum subequal, nearly as wide as long, each about three-fourths as long as third; joints 3 to 10 subequal in length but progressively wider; joints 5 to 7 each with a rather high tyloid on basal two-thirds, the tyloid ending abruptly and the joints appearing moniliform; tyloid on eighth joint lower; ninth narrow at base and expanded rather abruptly to apex of tyloid; last two joints lacking tyloids; apical joint nearly three times as long as tenth, distal half tapering. Carinulae on basal half of dorsal surface of propodeum

longitudinal, but diverging slightly; on apical half nearly transverse. Sides of propodeum finely striate.

Type.—U. S. N. M. No. 53431.

Type locality.—Brownsville, Tex.

Described from the holotype male, and one male paratype taken in 1921 by J. C. Bridwell.

Group UNCERTAIN

16. Trypoxylon (Trypoxylon) timberlakei sp. nov.

In the general shape of its head and abdomen as well as in its bidentate mandibles *timberlakei* resembles the species of the group *rufidens*, but lacks the U-shaped carina on its face and the thickened clypeal margin. The strongly convex supra-antennal area with a very low frontal keel, the median projection of the clypeal margin, and the nearly straight metapleural suture are more nearly as in *bidentatum, regulare,* and *backi* of the group *figulus*. It was felt that the assignment of *timberlakei* to a species group or the erection of a new group for it should be delayed until the male is known. This species differs from all others of this region in having the occipital carina bent forward to meet the hypostomal carina some distance from the median line of the ventral surface of the head.

Female.—Length 7 mm. Black, with mandible rufous and tegula and apices of fore and middle tibiae brownish. Wings hyaline, iridescent. Pubescence silvery white.

Head in facial view subcircular. Supra-antennal area strongly convex; punctures shallow and separated by at least a puncture's width; interspaces granular. Frontal keel very low and not on a median prominence; frontal furrow obsolescent. Vertex between punctures shiny and finely aciculate. Ocelli in an equilateral triangle; postocellar line three times of ocellocular line. Occipital carina on ventral surface of head meeting hypostomal carina some distance laterad of median line of head. Flagellum weakly clavate; first joint twice as long as wide; joints 3 to 9 progressively shorter and wider, ninth one and one-half times as long as wide; apical joint twice as long as ninth. Apical margin of clypeus impunctate; median fourth projecting rather strongly, apex of projection weakly emarginate in the middle. Apex of mandible bidentate, upper tooth shorter than the lower and separated from it by a narrow notch. (The teeth are more pointed than those of the species comprising the group *rufidens*.)

Mesonotum shiny, finely aciculate; punctures separated by one to two times a puncture's width; mesopleuron more coarsely and sparsely punctured. Metanotum finely punctured; metapleuron polished, metapleural suture nearly straight. Carinulae on dorsal surface of propodeum irregularly reticulate; sides of propodeum finely striate.

Abdomen slender, very weakly clavate; first tergite with sides diverging from base, apex one and one-half times as wide as base, median furrow very shallow and short; second tergite nearly as long as first.

Type.—In the collection of P. H. Timberlake.

Type locality.—Three miles east of Hesperia, Calif.

Described from a single female taken May 5, 1936, at *Acamptopappus sphaerocephalus* by P. H. Timberlake.

Species Erroneously Reported from North America

1. *Trypoxylon albitarse* Fabricius, in Palisot de Beauvois, Insects recueilles en Afrique et Amerique, p. 116, Hymen., pl. 3, fig. 1, 1811.

   This is apparently a specimen of *Trypoxylon politum* Say.

2. *Trypoxylon fuscipenne* Fabricius, in Palisot de Beauvois, Insects recueilles en Afrique et Amerique, p. 116, Hymen., pl. 3, fig. 2, 1811.

   This is apparently a specimen of *Trypoxylon striatum* Provancher.

3. *Trypoxylon unicolor* Palisot de Beauvois, Insectes recueilles en Afrique et Amerique, p. 116, Hymen., pl. 3, fig. 3, 1811.

   The specimen figured suggests a species of the African vespoid genus *Belonogaster* rather than one of the genus *Trypoxylon*.

4. *Trypoxylon excavatum* F. Smith, in Fox, Trans. Amer. Ent. Soc., vol. 18, p. 140, 1891.

   The specimens labeled "New York" and "Illinois" which Fox studied certainly belong to *excavatum*, but since no additional specimens of this West Indian species from those localities have been seen, the possibility of erroneous labels is suggested.

Bureau of Entomology
and Plant Quarantine,
U. S. Dept. of Agriculture,
Washington, D. C.

EXPLANATION OF PLATES

The drawings for the plates which accompany this paper were made, under the author's supervision, by Mrs. Eleanor A. Carlin, of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. On account of the great diversity of size of the male genitalia, it was impossible to have all drawn to the same scale; since those of the smaller species proved to be the most complicated, greater magnification of them was necessary. In the figures of entire genitalia, the left half is of the dorsal view and the right half of the ventral view.

Explanation of symbols applied to the male genitalia: *BR*, Basal ring; *Par*, Paramere: *Aed*, Aedeagus: *Vol*, Volsella.

PLATE 1

Figs. 1-25. Eighth sternite in male. 1, *Trypoxylon rubrocinctum* Packard; 2, *T. tridentatum* Packard; 3, *T. clavatum* Say; 4, *T. arizonense* Fox; 5, *T. californicum* Saussure; 6, *T. texense* Saussure; 7, *T. politum* Say; 8, *T. johannis* Richards; 9, *T. striatum* Provancher; 10, *T. xantianum* Saussure; 11, *T. spinosum* P. Cameron; 12, *T. apicale* Fox; 13, *T. regulare* Viereck; 14, *T. punctivertex* Richards; 15, *T. sculleni*, n. sp.; 16, *T. bidentatum* Fox; 17, *T. fastigium* Fox; 18, *T. backi*, n. sp.; 19, *Trypoxylon frigidum* F. Smith; 20, *T. pennsylvanicum* Saussure; 21, *T. johnsoni* Fox; 22, *T. richardsi*, n. sp.; 23, *T. carinatum* Say; 24, *T. bridwelli*, n. sp.; 25, *T. aldrichi*, n. sp.

PLATE 2

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PLATE 1

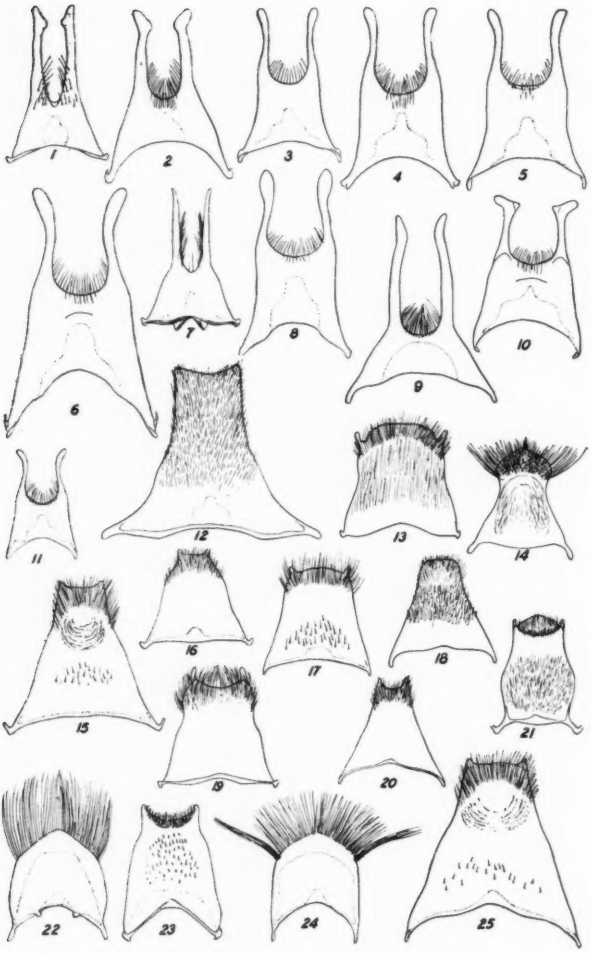
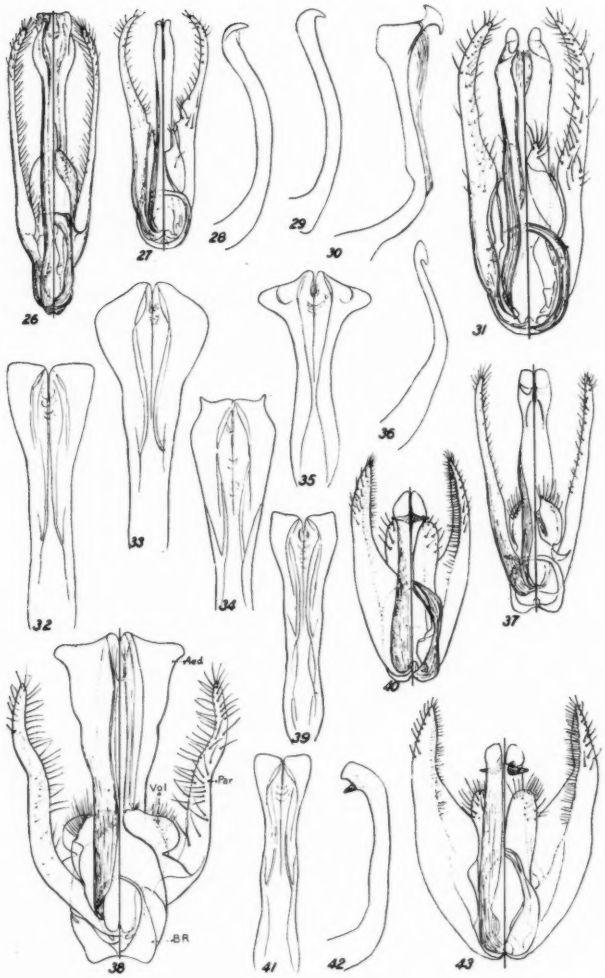


PLATE 2



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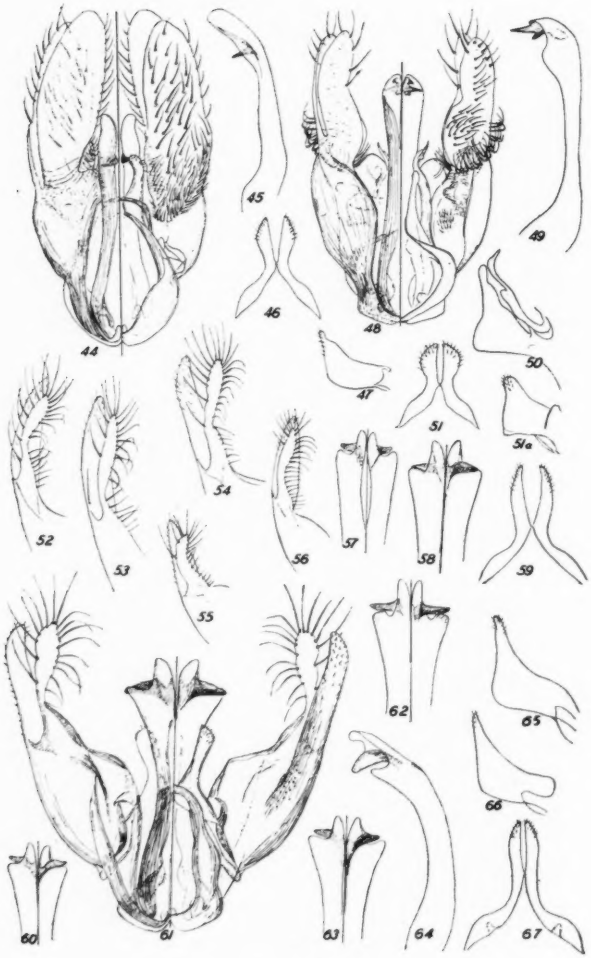

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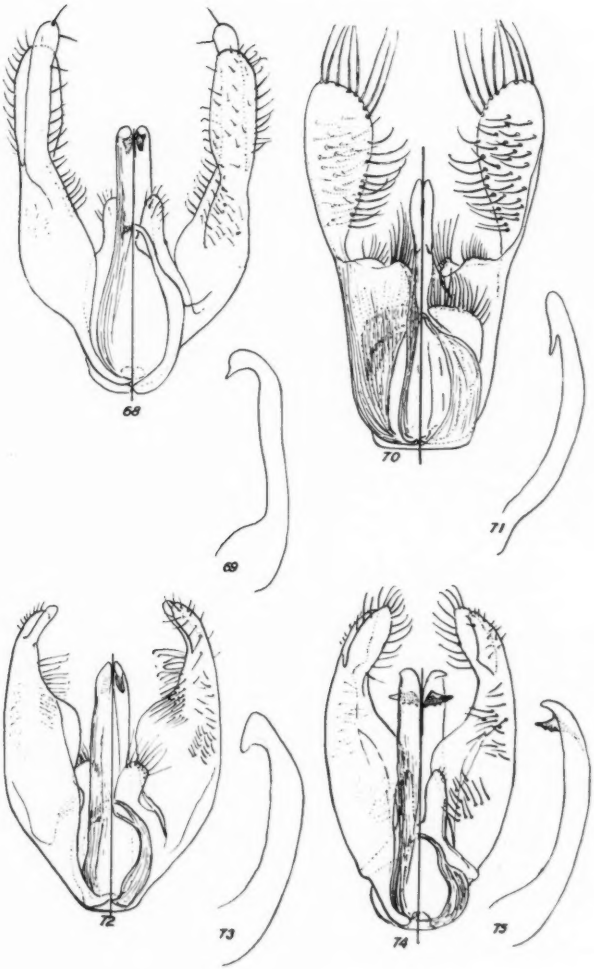

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A Quantitative Study of the Periodical Cicada With Respect to Soil of Three Forests*

Eldon J. Strandine

Although many references are available in the literature to the occurrence and the distribution of the periodical cicada, *Magicicada septendecim* (Linn.), few attempts have been made to study the influences of the soil on the distribution of this species. Marlatt (1907, p. 100) says, "Their variation in abundance is due in some cases to differences in the character of the soil and in others perhaps to varying surface conditions such as of timber, growth, etc.," and mentions that variations in the local distribution of a brood may occur.

Since the cicada oviposits in all kinds of trees and some herbs, several authors have concluded that oviposition sites in different species of trees are not a limiting influence in the distribution of the cicada. Marlatt (l. c.) says, "They prefer white oak groves, and are most abundant where the land is high and well drained and the soil is a rich sandy loam, with a sandy or soft clay sub-soil."

The number of cicadas has been estimated by counting the number of emergence holes in a given area. Thus, Marlatt (1907) records Kemp's observation in 1902 on Brood x near Frederick, Maryland, who found 84 openings in one square foot of ground surface, and 668 openings in a ten by four foot area.

Occurring in both the thirteen year race and the seventeen year race, are a number of smaller cicadas which have been named *cassinii*. Beamer (1931) and Davis agree that *cassinii* is a distinct species occurring in and with the *septendecim* broods, while Osborn (1902) says it is a distinct variety. Miller (1929) records 66.4% of the large variety *septendecim* and 33.6% of the smaller variety *cassinii* in the 1928 brood in New York state. Beamer (1931) concludes the *M. septendecim* is confined to oak-covered hills, while the *cassinii* is found in lowlands bordering streams, and mentions differences in songs, in the number of eggs in a nest, and the size of eggs. Smaller individuals, no doubt, would have these differences. A complete statistical study of a brood is needed before it can be definitely established whether *cassinii* can be separated from *septendecim* on the basis of size alone.

Since little quantitative work on the periodical cicada with respect to soil of different forests has been undertaken it was thought desirable to investigate this aspect of the problem.

There are seventeen broods of the seventeen year race of cicadas, each

* The writer wishes to acknowledge his indebtedness to Dr. Orlando Park of Northwestern University for helpful criticisms and suggestions.

brood occurring in a given year in a definite range in the northern part of the United States. Brood XIII is the one that appears in the Chicago area, having last appeared here in 1922 and now again in 1939.

Methods

Three different forests were studied, namely, a maple climax forest in Pilcher Arboretum at Joliet, Illinois; a black-oak forest of Palos Park, Cook County, Illinois; and a red-oak-white-oak-maple forest of Carle Woods along the Desplaines River in Cook County, Illinois.

Twenty quadrats (one square meter each) were investigated at Carle Woods. The number of nymph cases per quadrat and the length of such cases were recorded. Samples of top-soil, sub-soil, and chimneys or cones were obtained from each quadrat and brought into the laboratory for analysis. The soil moisture was determined by air drying and calculated as the percent of the dry weight. The organic matter was assayed by ignition, while the pH was determined electrometrically by a Coleman Potentiometer.

The same procedure was followed on ten quadrats at Palos Park and on ten quadrats at Joliet, Illinois. In these last two areas the number of emergence holes per quadrat was also determined.

Results

Although showing some variation, the number of nymph cases per square meter shows a positive relationship with the number of emergence holes per square meter (Fig. 1). Therefore, the number of nymph cases per square meter may be an index of the density of the population emerging in a given area.

There is great variation in the density of the cicada population in the three forests, the number of cases averaging 13 per square meter (51,397 per acre) in the maple forest, 32 per square meter (127,885 per acre) in the black oak forest, and 50 per square meter (202,876 per acre) in the red oak-white oak-

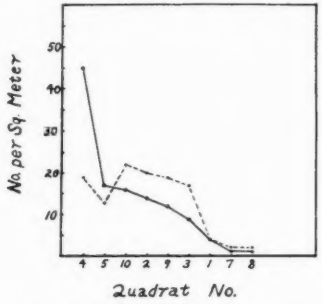

Fig. 1. Comparison of the number of Cicada nymph cases and emergence holes in a sugar-maple forest. (Solid line represents the emergence holes, while the broken line represents the nymph cases.)

maple forest. Since the average alcohol-dried cicada weighs about 0.154 grams, there is suddenly available in the red oak-white oak-maple forest 31,243 grams of dried cicada protoplasm per acre. This great increase of food is especially available to birds who prey upon the cicadas.

It has been observed that abundant adults flying in the upland oak community of the Chicago area between June 10 and 28, 1939, were being fed upon by the starling, English sparrow, bluejay, robin, and yellow-billed cuckoo.[1] Beamer (1931) among others, recorded that birds fed upon the cicadas, so that this increase in food is apparently being utilized. This periodic change in animal protein is notable in that it increases the food supply in the upper third of the Eltonian pyramid. This may to some extent offset the know detrimental effect of the cicada upon the foliage of important tree constituents.

The size of the nymph cases from the different forests is shown in the following table.

TABLE 1.—Size Ranges (mm).

	Size Range	Mode	Average
White oak-red oak-Forest	19.0-30.0	25.0-25.9	25.0
Black oak Forest	21.0-27.0	24.0-24.9	23.9
Maple Forest	16.0-27.0	22.0-22.9	24.2

Figure 2 demonstrates that a uni-modal curve is obtained in plotting the total cicada population from each forest, indicating that size is not a reliable factor in separating the *cassinii* variety from the *septendecim* variety. The largest nymphal cases were found in the red oak-white oak-maple forest at Carle, Illinois, while the smallest occurred in the maple forest.

The amount of moisture in the soil in the three forests is shown in the following table.

TABLE 2.—Range in Soil Moisture (%)

	Top-Soil		Sub-Soil		Chimneys
	Range	Av.	Range	Av.	Range
White and red oak Forest	8.47-47.50	27.83	5.40-27.19	13.54	3.54-31.87
Black oak Forest	20.63-42.75	30.75	12.52-76.65	22.30	12.56-100.0
Maple Forest	23.28-43.39	32.97	17.48-56.61	26.20	20.74-42.37

This table indicates that the maple forest, which had the fewest cicadas, had the moistest soil. This area is subject to flooding in the spring, and this excessive moisture is undoubtedly detrimental to the nymphs living in the soil. The red oak-white oak-maple forest, and the black oak forest have abundant moisture for cicadas, but not enough to be detrimental.

It must be remembered that the unusually great amount of soil moisture in the black oak forest was due to rains which fell a few days prior to the collecting. Several years' observation and measurement have shown that this black oak forest is the dryest of the three areas studied, and the maple forest is the wettest.

[1] Personal communication from Professor Orlando Park.

In the red oak-white oak forest (Fig. 3) there is a positive relationship between the amount of soil moisture per quadrat and the number of nymph cases per quadrat. This relationship also exists in the maple forest, while in the black oak forest it is not so evident. We may conclude, that within a

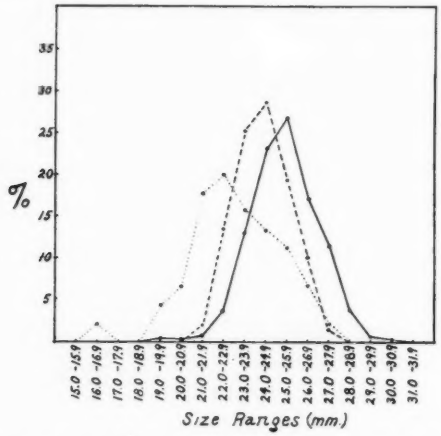

Fig. 2. Percentage of size ranges of Cicada nymph cases in three forests. Solid line represents size variation (based on 910 nymph cases) in a red oak-white oak-maple forest; broken line represents size variation (based on 290 nymph cases) in black oak forest; and dotted line represents size variation (based on 45 nymph cases) in a sugar maple forest.

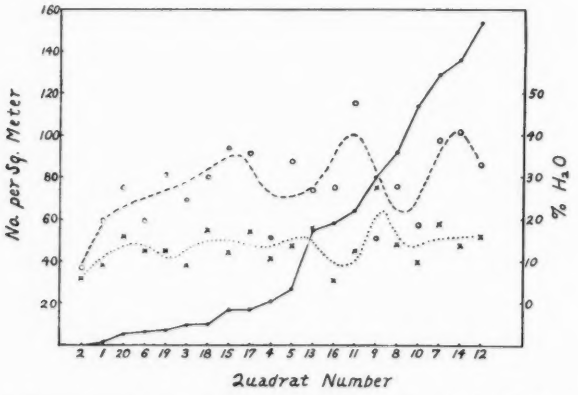

Fig. 3. Comparison of moisture in top-soil (broken line) and sub-soil (dotted line), and the number of nymph cases (solid line) in a red oak-white oak-maple forest.

forest, dry areas have a smaller cicada population than the more moist areas. A very moist forest such as the maple forest which is subject to spring flooding has a very small cicada population. Excessive moisture may act as a limiting influence in the cicada population. It is also interesting that the smallest nymph cases were found in the very moist maple forest.

The pH reaction of the soil in the three forests is shown in the following table (Table 3).

TABLE 3.—Soil Reaction (pH)

	Top-Soil		Sub-Soil		Chimneys
	Range	Av.	Range	Av.	Range
White and red oak Forest....	4.90-6.80	5.85	4.60-6.60	5.61	5.10-7.00
Black oak Forest	5.15-6.00	5.58	4.25-5.00	4.70	4.90-5.40
Maple Forest	5.55-6.95	6.39	4.20-6.80	5.89	5.70-7.00

Figure 4 demonstrates that there is a positive correlation between the pH of the soil and the number of cicada cases per quadrat. Acid areas within a forest have fewer cicada nymphs than more alkaline ones. This relationship is not so evident in the case of the black-oak forest, due to the excellent drainage of this area. The range in variation in pH in the three forests is not great enough to account for the variations in the population. Very acid soil may serve as a limiting influence in the distribution of the cicada.

The acidity of the chimneys in most cases was intermediate between that of the top-soil and sub-soil of the quadrat on which they were found.

The following table shows the amounts of organic matter in the soil from the three forests studied.

TABLE 4.—Organic Matter

	Top Soil		Sub-soil		Chimneys	
	Range	Av.	Range	Av.	Range	Av.
White oak-red oak F.....	7.05-28.00	13.74	2.16-12.69	4.37	2.09-16.86	7.58
Black oak Forest.....	12.29-16.01	13.51	2.86- 5.33	4.17	4.41-28.63	10.63
Maple Forest	9.06-17.44	12.55	4.85-22.28	9.22	7.19-16.60	11.53

There is not a significant difference in the amount of organic matter in the top-soil from the three forests. (Table 4) The sub-soil in the maple forest is a rich loam and has more organic matter than the other two forests.

Within a given forest (Fig. 5) there is some relationship between the organic matter in the soil and the number of nymphs per quadrat. Organic matter, however, is not an important influence since the nymphs do not feed upon it, but rather upon the juice of plant roots.

The amount of organic matter of the chimneys or cones was intermediate between the top-soil and sub-soil, indicating that the chimneys are composed of both the top-soil and sub-soil. The study of the pH of the cones with respect to the soil also lends support to this view.

There is some correlation between the amount of organic matter in the soil and the pH of the soil. Soils with low organic matter are more acid than

those with more organic matter. This is no doubt due to the release of alkaline ions from the decaying vegetation. The more organic matter present, the greater the number of alkaline ions and the greater the pH.

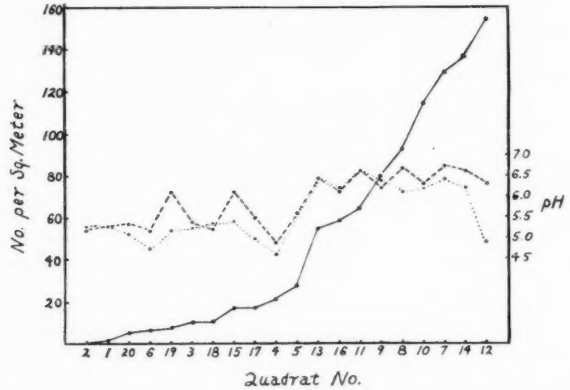

Fig. 4. Comparison of the pH of the top-soil (broken line) and the sub-soil (dotted line), and the number of nymph cases (solid line) in a red oak-white oak-maple forest.

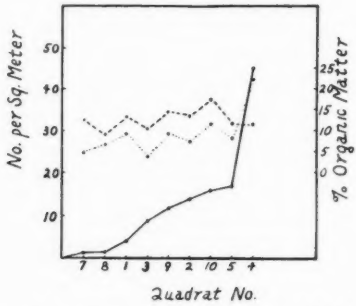

Fig. 5. Comparison of the organic matter in the top-soil (broken line) and the sub-soil (dotted line) and the number of emergence holes (solid line) in a sugar maple forest.

Conclusions

1. The number of emergence holes of *Magicicada septendecim* is correlated with the number of nymph cases per square meter quadrat; the number of nymph cases per quadrat is an index to the size of the cicada population.

2. The number of cicadas in three forests were compared, a red oak-white oak-maple forest having the greatest cicada population (202,876 per acre),

while a sugar maple forest had the smallest population (51,397 per acre). This represents an enormous increase (31,243 grm. dried protoplasm per acre) in the available food for birds.

3. A statistical study of the cicada cases collected as noted demonstrated that it was impossible to separate the form *cassinii* from the form *magicicada* on the basis of size alone.

4. The size of the cicada population is correlated with the amount of soil moisture; excessive moisture apparently acts as a limiting influence in the distribution of the periodical cicada, *Magicicada septendecim*.

5. Within a given forest there is a correlation between the amount of soil moisture on a given quadrat and the number of cicada nymphs in the soil.

6. Acid soil may act as a limiting influence in the distribution of the cicada population in a given forest, although the variation in the three forests studied is not great enough to be significant.

7. Organic matter of the soil is of less importance in influencing local cicada distribution.

8. The pH and organic matter of the chimneys is intermediate between the top-soil and sub-soil, indicating that both contribute to the formation of the chimney.

9. The study of the soil demonstrates that there is a positive correlation between the pH of the soil and the amount of organic matter present in the soil, acid soils having low amounts of organic matter.

10. Of the soil influences studied, soil moisture is the most significant in determining the local variations in the distribution of the cicada.

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NORTHWESTERN UNIVERSITY,
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Studies on the Turbellarian Fauna of the Norfolk Area, I

Frederick Ferdinand Ferguson and E. Ruffin Jones, Jr.

Macrostomum ruebushi var. *kepneri** is a flat-worm of the Family Macrostomidae, of the sub-order Opisthandropora and of the order Rhabdocoela.[1]

This actively swimming form may be collected at high tide in the reeds and muddy waters of Tanner's Creek at the Colley Avenue Bridge, Norfolk, Virginia, at a depth of from two to four feet. Many mature specimens were studied alive with the vaseline cover glass technique. Material fixed in Beauchamp's and Zenker's fixatives which was sectioned at 8 micra and stained in Delafield's and Heidenhain's, gave good histological results. Both sectioned and total-mount material has been deposited in the United States National Museum at Washington, D. C.

The animal (Fig. 1) is shaped like a typical *Macrostomum,* dorso-ventrally compressed with a rounded anterior end. There is a singular absence of a spatulate tail, this region being somewhat pointed in a freely-swimming specimen. The animal is approximately the same width throughout its length. Average measurements show the length to be 1.12 mm. and the width about .16 mm. This flat-worm is colorless except for the brownish enteric contents. Many unusually large, granular amoebocytes (10.5 micra) may be noted in the lateral parenchyma.

The epidermal epithelium is composed of a flattened layer of cells, pentagonal when viewed in dorsal optical section, tall and columnar (6 micra by 1.5 micra) when vieved laterally in sectioned material. The dorso-anterior epithelium is thicker, the cells measuring 7 micra by 1.5 micra. The epidermis is well supplied with oval glands (3 micra by 6 micra) which open externally and are presumably mucus-producers. The external body surface is entirely clothed by a fine coat of cilia approximately 6 micra in length. The anterior region is provided with short tufts of sensory haits about one-third longer than the cilia. A sparse adornment of spines which measure up to 22 micra in length may be seen posteriorly. The rod-shaped adenal rhabdites occur in groups of 7 to 9 and are about 7.5 micra long. They are few in number and are located laterally upon both the ventrum and the dorsum, there being none down the mid-line of the body. Well defined "Rhabditen-strassen" may be discerned anteriorly originating above and below the "brain" commissure and

* *Macrostomum ruebushi* var. *kepneri* is named for Dr. W. A. Kepner of the University of Virginia.

1 Meixner (1938) in his recent revision of the system of classification in the Turbellaria included the Family Macrostomidae in the Order Macrostomida.

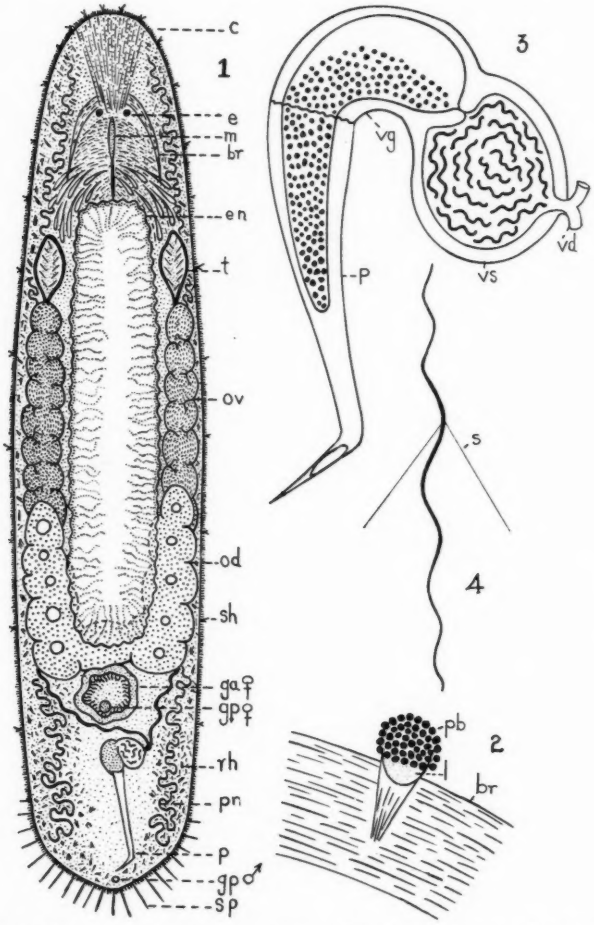

Fig. 1. Dorsal view showing gross anatomy ×80. br, "brain"; c, cilia; e, "eye"; en, enteron; ♀ga, female genital atrium; ♀gp, female gonopore; ♂gp, male gonopore; m, mouth; od, oviduct; ov, ovary; p, penis; pn, protonephridium; rh, rhabdites; sh, sensory hairs; sp, spines; t, testis.

Fig. 2. Detail of "eye" ×290. br, "brain"; l, "lens"; pb, pigment beaker.

Fig. 3. Male Sex Apparatus ×623. p, penis; vd, vas deferens; vg, vesicula granulorum; vs, vesicula seminalis.

Fig. 4. Mature sperm-cell: ×623. s, seta "Nebengeisseln."

ending at the anterior terminus of the body. The pharyngeal walls are well supplied with streamers of rhabdoidal glands whose products are tiny "Rhammiten," very thin, long, and spindle shaped. Numerous large (3 micra) ovoidal "Stabchen" rim the walls of the female genital atrium and may be noted as a rosette over the atrium in a dorsal perspective.

The "brain" is not of the usual smooth semi-lunar contour so common to the genus but is semi-lobate. It is located equidistant from the dorsal and ventral sides of the body near the anterior end. There are noticeable dorsal projections of nerves, and in a frontal longitudinal section two prominent anterior ones may be noticed between the "eyes." The lateral longitudinal nerves are large and are appended to either ganglionic half of the brain. The commissure between the ganglia is not a prominent feature. The paired "eyes" (Fig. 2) lie immediately behind and dorsal to the "brain" being partially embedded in it. The pigment-cup and "lens" compose an organ of ovoidal shape which retains a tenuous connection with the "brain." The pigment-cup composed of very small dark brown globules (2 micra) measures 8 micra in length while the "lens" is 6 micra long.

The mouth is a slit-like opening guarded by two ciliated lips located in the ventral surface slightly posterior to the "eye"-level. It communicates directly with a pharynx simplex which is about twice as long as the mouth opening. In optical section the pharynx appears almost rectangular in shape and it opens directly into the enteron by means of a ventral trough. Two types of glands attend the pharyngeal cavity; the "Rhammiten" mentioned above, and a system of radiating streamers which extend as far posterior as the testes and which supply a product of granular nature to the pharynx. These gland-cells are slender and pyriform in shape. The pharyngeal walls are supplied with a dense coat of cilia which resembles that on the external body surface. The unusually strong epithelium of this organ is made up of closely packed columnar cells which are about 6 micra tall.

The rod-shaped, slightly diverticulated enteron (about 630 micra long) extends posteriorly to the common oviduct. The epithelium is ciliated and is provided with a multitude of very small enteric gland cells. Strong longitudinal muscle fibers course upon either side of the enteron. They are about 2 micra to 4 micra in thickness and are most prominent in the tail region.

The excretory system, composed of lateral protonephridial tubules, extends the length of the body, becoming quite prominent at the level of the "eyes" where the tubules measure about 2 micra in diameter. Very large (10 micra long) flame-cells are appended to the terminal branches of this system. The external opening was not observed.

The male reproductive system in this hermaphroditic form is made up of testes, vasa deferentia, vesicula seminalis, vesicula granulorum, prominent penis-stilette and male gonopore. The ovoidal, smooth-walled testes are

located latero-ventrally in the last of the first body third. Nurse-cells in these organs measure from 3 micra to 4.5 micra in diameter. From the posterior tip of each testis, a vas deferens extends caudally until it reaches the posterior margin of the enteron where it bends mesially to unite with its counterpart of the opposite side at a point slightly to the right of the mid-line of the body. There is no "false vesicula seminalis" developed at the juncture of the two tubes. The ductus seminalis empties directly into a small (30 micra diameter) vesicula seminalis (Fig. 3) of strongly developed muscular walls and a simple ciliated epithelium. There are no ciliated chambers such as are present in most other American Macrostomums. The sperm-cells lie rolled into a bolus awaiting passage through the short ductus ejaculatorius into a comparatively thin-walled vesicula granulorum packed with hyaline granules. These granules, arranged in small platelets, extend far into the male genital canal of the penis-stilette. The stilette (Fig. 3) is of the *M. ruebushi* Ferguson type, being a simple extended funnel with a terminal bend. The opening (15 micra long) lies adjacent to the very sharp point and may be seen as a lateral aperture. The stilettes have an average length of 67.5 micra with a basal dimension of 15 micra. The penis-stilette communicates directly with the male gonopore which has a singular position at the very posterior tip of the body. This does not occur in any other Macrostomum.

The mature sperm-cell (Fig. 4) as observed in material taken from the vesicula seminalis is a thin filament (up to 75 micra in length) of undulant movement and possessing no cellular differentiation except for a pair of "Nebengeisseln" or setae (3 micra long) which are directed latero-posteriorly from the mid-cell. The usual chromatin granules are not visible in living cells.

The female reproductive system consists of ovaries and oviducts; a genital atrium, a female gonopore and accessory glands. The paired, heavily indented ovaries are embedded in the latero-dorsal portion of the parenchyma and lie entirely within the posterior two-thirds of the body. The oöcytes are quite small measuring only 3 micra in diameter on the average. The oviducts course mesio-dorsally from the mesial margin of the posterior region of each ovary to unite in the common oviduct under the posterior end of the enteron. This common oviduct extends postero-ventrally to communicate with the female genital atrium. The atrium may be distended with a spherical egg of reddish-brown color measuring about 130 micra in diameter. The walls are so developed as to prevent collapse, however, so that the atrium may always be observed as a discrete structure even though it may not contain an egg. The ciliated epithelium of the atrium is quite tall (15 micra) and glandular. The female gonopore is a mid-ventral opening limited by ciliated lips and is located slightly postero-ventral to the atrium.

The chromosomes in this form are so small (2 micra long) as to prevent proper study of them.

The taxonomic placement of this form involves a consideration of, and a comparison with, the difficult *M. ruebushi* Ferguson group as outlined in the

monograph upon the genus now in press. If the morphology of the penis-stilette is taken as the chief diagnostic character then a comparison between this form and *M. ruebushi* var. *frigorophilum* Ferguson would be pertinent since the stilettes of the two compare favorably. The morphological features of *M. ruebushi* var. *frigorophilum* Ferguson which differ from the presently described form are herein listed.

(1) *M. ruebushi* var. *frigorophilum* Ferguson has a body shape resembling a large barge with a slightly pointed anterior end and an abruptly truncated posterior end.

(2) It measures 1.6 mm. by .4 mm.

(3) Rhabdites are unusually numerous throughout the epidermis.

(4) There are no spines and the sensory-hairs are located mostly at the extremities of the body.

(5) The "brain" is bi-ganglionic and has a clearly defined median commissure.

(6) The "eye" is a cone shaped structure with a rim of pigment globules.

(7) The mouth is an unusually long slender opening.

(8) The testes are located in the caudal region of the anterior half of the body.

(9) The vesicula granulorum is provided with ciliated chambers.

(10) The penis-stilette measures 88 micra in length and has almost a right angle bend terminally. The opening extends up to the sharpened tip.

(11) The male gonopore is located about 32 micra from the posterior body end.

(12) The sperm-cell is a thick spindle shaped structure differentiated into tail, body, feeler and lateral setae and measures about 52 micra in length.

Macrostomum ruebushi var. *kepneri* offers clear distinction from the features noted above in *M. ruebushi* var. *frigorophilum* and from all other previously described Macrostomums.

Macrostomum ruebushi var. **kepneri** var. nov.

Body anteriorly rounded, posteriorly semi-pointed, colorless, ciliation consists of spines, sensory hairs and cilia, rhabdites lacking in mid-line of body, testes smooth-walled, ciliated chambers lacking in vesicula granulorum, penis-stilette (up to 67.5 micra long) a simple funnel with sharpener bent terminus, sperm-cell a thin filament, female genital atrium strongly developed, body length up to 1.12 mm. (Paratype; U. S. N. M. No. 20526).

SUMMARY

This paper describes the anatomy of a new flat-worm of the genus *Macrostomum* which attains an intense morphological variation in America. While it presents the general plan of a *Macrostomum* it has many unique features, the most singular being the absence of rhabdites in part of the epidermis and the presence of a male gonopore which is almost terminal in position.

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The Behavior of Limpets with Reference to Their Homing Instinct

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Introduction

The homing instinct of limpets has long been a subject of speculation among naturalists, both amateur and professional. Aristotle stated that the limpet leaves its place on the rocks to go out to feed. This was confirmed by Reaumur. On the other hand, Borelli and others asserted that the limpet remains all its life fixed to one spot.[1] The literature of the early 19th century contains numerous inconclusive observations. Lukis (1831) and Roberts (1847) for example each marked one individual of the European genus *Patella* and observed its movements. They disagree entirely in their findings. Lukis states that the limpet moved at night when covered by the tide; Roberts, that it moved by day, traveling when the tide was out.

Little further work was done on the behavior of *Patella* until the latter part of the nineteenth century, when a search was begun for the exact location of the homing sense. Davis (1885, 1895, 1903) found that his specimens returned to their scars from distances up to three feet, but was unable to find the sense used. He cut off the cephalic tentacles of two limpets and carefully washed with soap and water the surface of the rock between a limpet and its scar to eliminate possible odors. Discovering no beaten tracks, he believed that the mantle tentacles, small projections from the mantle with tactile cells, might be the agents involved. Morgan (1894), supposed the head tentacles to be the instrument used by limpets in returning to their scars, and found on forcibly removing the animals, that the number of returns bore an inverse ratio to the distance, only 5 of 36 limpets returning a distance of 6 inches. Pieron (1909a, 1909b) proposed some kind of kinaesthesis or "muscular memory" because he observed the animals to go and return along the same path, even after the rock was destroyed or altered in various ways. He also performed some removal experiments and found that 5 of 6 individuals returned from distances or 4 cm. or less, 2 of 5 returned from 5-10 cm., and only 2 of 9 returned from 10-20 cm. Those *Patellae* which live "at high levels" and leave their scars only very infrequently, if ever, were found to have little or no homing ability, since none of the 6 removed from their homes were able to return from distances of 1-5 cm.

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1 Jeffreys: *British Conchology III;* p. 236.

Hawkshaw (1879) thinks that since limpets cannot adapt themselves to a different form of rock surface daily, they must return to the same place of attachment, chosen for its suitability to the shell. Robertson (1884) kept a limpet surrounded by pegs driven into the rock so that the animal was not able to move and found that it was still alive after 124 days. Russell (1907, 1909) marked and observed thirteen limpets and found that the larger ones (20 mm. and up) either remained in place or moved just a few millimeters and then returned, but that the smaller ones moved much more and did not appear to have definite homes. One of the larger limpets remained in the same place for six months.

In the later literature there is a definite trend away from the term "homing instinct." Loppens (1922) states that limpets of the genus *Patella* may change their homes for various reasons — if food is lacking, if the rock crumbles, or if for any other reason the scar becomes undesirable. Orton (1929, 1914) says that the bulk of the larger individuals retain a definite position for long periods, and that a "changing of site" is unusual for medium to large individuals in most habitats but occurs in some, e.g., on smooth and wet surfaces, where there is less need of returning to a home since the shell will fit in many places.

Concerning the movements of the North American limpets of the genus *Acmaea* comparatively little has been published. Two of the three papers on this subject deal with the Pacific coast species of *Acmaea* and *Lottia;* the third is on the Atlantic coast species *Acmaea testudinalis.*

Willcox (1905) could find no evidence of a homing instinct in *Acmaea testudinalis.* Of the Pacific coast studies, the first, by Wells (1917), is based on daily observations of thirty limpets at La Jolla, California, combining four different species of *Acmaea* and *Lottia gigantea.* These were distributed over "all possible situations, some on horizontal rocks, some on vertical ledges, some exposed, some not, etc." so that he had very few members of any one species in any one type of situation to form a population from which to determine the typical behavior of that species in that type of subhabitat. He gives some graphs of the movements of his marked limpets, from which he concludes that they came back to the same place and therefore have a homing instinct. However, a perusal of his graph of the movements of *A. spectrum,* now called *scabra,* and of *A. scabra,* now called *limatula,* reveals no behavior patterns which could be called a homing instinct. He does say that there is a wide variation in the behavior of different individuals. He reports *Lottia gigantea* to be a "very consistent homer" with individual variation reduced to a minimum, but he marked only seven of these, which he found to return daily to recognizable depressions on the rock's surface. However, in another place he says that one of these was found twelve inches from home.

In the second Pacific coast study, by Richardson (1934), at Laguna Beach, California, no evidence whatsoever was found of a homing instinct in *Lottia gigantea.* Richardson marked fifteen individuals each of *A. persona,* now called *digitalis,* and of *L. gigantea,* and found that *Acmaea* remained day after day in the same or very near the same spot; but not *Lottia.* Individuals of the

genus *Lottia* which were moved a short distance did not return to the original site. Some settled in new cracks; others, following no definite course, continued to wander around. Richardson concluded that the owl limpet, *L. gigantea,* shows nothing even analagous to the homing instinct.

Methods

This study was carried on in the vicinity of Moss Beach, San Mateo County, California, during the months of May and June, 1939. Twelve groups of the genus *Acmaea,* totaling 223 individuals, were observed and the positions of each individual noted at frequent intervals for periods of from two to three weeks. Nine of these groups were on the top and sides of Sand Rocks, large sandstone masses which are eroded remains of a Pleistocene sand shelf projecting about fifteen feet above the substrate and lying about fifty feet seaward from the mean high tide line; the tops of the rocks are about seven feet above zero tide level and therefore splashed by each high tide. The remaining three groups of limpets were on a granite cliff face in a protected cove 200 yards north of the Montara Lighthouse. The distribution of the species in the groups is given in Table 1.

TABLE 1.—Distribution of species of *Acmaea* in groups marked

Groups	*A. digitalis*	*A. scabra*	*A. persona*	*A. pelta*	*A. scutum*
i	3	22	1	0	0
ii	0	17	6	2	0
iii	8	4	2	1	0
iv	1	14	0	0	0
v	3	16	0	1	0
vi	0	0	4	5	2
vii	3	2	0	0	0
viii	4	2	0	4	6
ix	0	9	0	4	0
x	11	0	0	0	0
xi	25	0	0	0	0
xii	23	0	0	0	0
Total	81	86	13	17	8
Grand total					205*

Limpets selected at random, regardless of size or species, were numbered consecutively with red fingernail polish, the corresponding numbers being painted also on the substrate nearby. The anterior and posterior margins of the shell were indicated on the substrate to facilitate accurate measurements of small movements. Polish of different shades was used in contiguous groups to prevent confusion.

The localities were selected to give as great a range of physical factors as possible. The relation of the groups to these physical factors is summarized in Table 2.

* Eighteen limpets disappeared (left their scars and could not be found subsequently) during the course of the observations and are not included in these totals.

TABLE 2.—Relation of the groups of limpets marked to various physical factors in the environment.

Tidal exposure to air	High (6-8 ft. above o tide): iii, iv, v, x, xi Medium (4-6 ft. above o tide): i, ii, vii, xii Low: (3-5 ft. above o tide): vi, viii, ix
Substrate	Granite: x to xii Sandstone: i to ix
Exposure to wave shock	Least (Substrate horizontal, high): iv, v More (Substrate vertical perpendicular to wave): groups viii, ix, x, xi Most (Substrate vertical, parallel to waves): groups i, ii, iii, vi, vii, xii

Observations of the positions of the limpets with relation to the marked "base," the point at which they were when first painted, were made at intervals of one or two days as time and tide permitted, usually from 3 a.m. to sometime in the afternoon. The distance of each limpet from its base was carefully estimated by means of known spans of the hands. The distance between two consecutive positions has been called "observed distance covered." Of course, the limpets may have moved much farther than the measurements indicate in getting from one position to the next. As an aid in locating the bases each time, a map of the area of each group was made. The number of observations made on each group varied from nine to thirteen, because of differences in starting time and in accessibility during the higher low tides.

Since the limpets were never seen to move, it was believed that they moved and foraged for food only when covered by water, i.e., when the tide was in. To test this hypothesis, the authors remained on the top of Sand Rock, during the lower high tide (4.3 feet by the tide table) of June 16, 1939 from 10 a.m. until 2 p.m. Small specimens of both *A. scabra* and *A. digitalis* were observed to move when covered or splashed by water. The routes taken were plotted on a map at intervals of 3-10 minutes (see fig. 5).

At the end of the observation period, some of the animals of Group IV were moved a short distance from their respective bases and observed at later low tides to see if they really had a homing instinct.

Results

Of the 223 limpets marked and observed, 18 were lost during the course of the study and hence are not included in the tabulated results. Eighty-three of the remaining 205 limpets (including 8 members of *A. scutum*) left their respective bases but were never observed to return to them. These individuals obviously cannot be used as a basis for postulating a homing instinct. Of the remaining 122 only 29 were observed to be away from their base at one or more times and then at some later time to have returned to it, as follows: *A. digitalis*, 17; *A. scabra*, 5; *A. persona*, 2; and *A. pelta*, 5. Of eight members of *A. scutum* none was ever observed to return to its base. As shown in figure 1, the greater percentage of those which returned apparently moved not more than two or three inches away from their base. The minimum paths of movements of certain ones of the returning specimens are plotted in figures 6-12.

The remaining 93 limpets were never observed to leave their marked base; 77 of these were *A. scabra*. It is possible, of course, that some individuals did move but returned to their base before the next period of observation; however, it is improbable that all of them could do this. Furthermore, in some cases the fingernail polish which marked the anterior and posterior edges of the shell dried to form a seal between the shell and substrate, and remained unbroken. This seems to show that limpets may remain in the same place for long periods of time, as has already been stated by Robertson (1884), Russell (1907), and Pieron (1909), in connection with *Patella*.

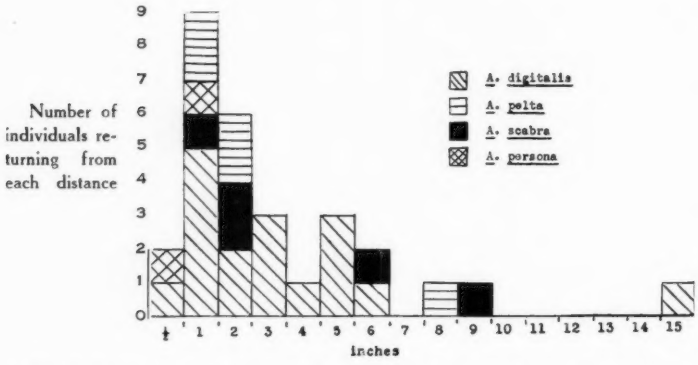

Fig. 1. Greatest distances from which individuals of the genus *Acmaea* were observed to return to base.

Figure 2 shows the greatest observed distance the various species moved from their base. Since the anterior and posterior margins of the shell were outlined on the substrate with polish, movements as small as ¼ inch and rotations as slight as 15 degrees could be detected. As will be noted later, numerous small *A. scabra* were seen to move on Sand Rocks when covered by water at high tide. However, no members of this species of the size used in this study were seen to move under these conditions even though situated in surroundings identical with smaller, mobile individuals.

Figure 3 shows the total observed movements by species, in arbitrarily selected distance groups. In general, with regard to the total minimum (observed) distance moved the limpets may be divided into three groups: The first of these is the *A. scabra* group, of which 90 percent (77 individuals) were never seen away from their base, and in which only one of the individuals that did roam (no. 8) covered a total distance of as much as 50 inches. The next division, the *A. digitalis* group, tended to vary to a greater extent. Whereas 20 percent of them were never found away from their bases, the remaining 80 percent ranged from 1 inch to 150 inches or more, most, however, totaling not

more than 70 inches. The variability of this group is seen to be considerably less than that of the third group, namely, *A. persona-pelta-scutum*, whose members almost without exception were found away from their base at some time or other and extended their activities into the greatest distance classes. The correlation particularly of *pelta* and *persona* in their distribution among the different classes is more clearly brought out by the percentage comparison of figure 4. One should keep clearly in mind the numbers of specimens of each species upon which the graph is based to avoid placing too great an emphasis on a percentage comparison.

Figures 6-25 show minimum movements of representative individuals of each species. The ringed dot "B" is the marked base and all other locations at different readings are plotted from field notes with relation to this point. The graphs are presented to show the variation of paths not only between species but within the species as well and are in no way intended to be used in comparing the species as to distance travelled or greatest distance from base. The plotted paths show clearly that the wanderings of the limpets are random.

The greatest distance any limpet was observed from its base was 123 inches, a record made by *A. persona* in Group VI. An *A. pelta* of Group VI went the greatest observed distance, 183 inches, that is, the cumulative distance between consecutive daily positions.

During the period of observation there were noted twenty-nine instances of one *Acmaea*, marked or unmarked, occupying the base of another. The greatest number of these replacements occurred in Groups III and XI, which resembled each other with regard to crowding and limited number of desirable locations. There was a great deal of activity in these groups, and a tendency for individuals to move into a position immediately upon its having been vacated by some other individual. Frequently a number of small limpets occupied the marked base of a larger specimen. Only in one or two instances did it seem likely that the departed individual would have returned had there been no other limpet in the base.

In order to determine if the larger *A. scabra* which were never seen to move would return to their pits, ten specimens were moved from their positions on the substrate and placed 2-13 inches away. The results appear in table 3.

TABLE 3.—Record of movements of *A. scabra* which were removed from base

No.	Surface	Distance removed from base 6/15	Position later 6/16	Position later 6/17
1	In shallow pit	8″ E	same†	same
2	On flat surface, no pit	12″ SW	same	same
3	On flat surface, not pit	11″ SW	gone‡	gone
4	In very shallow pit	10″ SW	gone	gone
5	In deep pit, No. 4's old place	7″ SW	same	same
6	In shallow pit, No. 5's old place	2″ W	same	same
7	In shallow pit	4″ N	same	same
8	In shallow pit	5″ NW	same	9″ N
9	On flat surface	4″ E	2½″ E	in base
10	On flat surface	8″ E	gone	gone

† Remained in the spot in which it had been placed.
‡ Disappeared from the vicinity and could not be found.

The return of No. 9 to its original pit was probably a matter of chance, since this was the only sheltered spot within a radius of six inches, being protected by a raised portion of the rock; furthermore, this limpet was among the closest to the water and therefore subject to spray. The only other one which moved, no. 8, moved directly away from its base. It was the closest one to the water. There was a general tendency for individuals placed in deep pits to stay there, and for those on plane surfaces to move or be washed away.

Although other workers in the same area have observed both *A. pelta* and *A. persona* to move when uncovered at low tide, we did not see any individuals of any species actually in motion at any time during the periods of observation except as noted below. There were only a few members of *A. pelta* and *A. persona* in the groups under observation, and with the great number of limpets

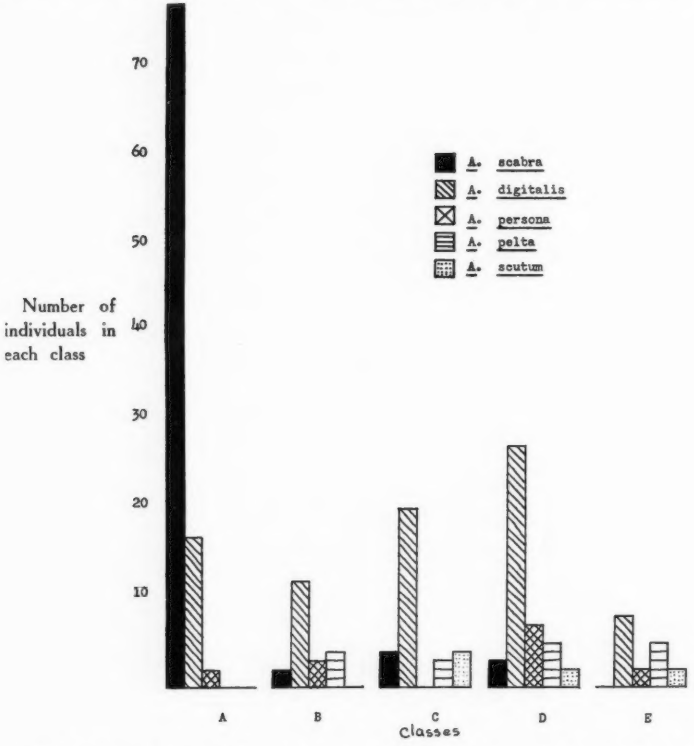

Fig. 2. Greatest observed distance from base, individuals arranged in classes. Class A, always on base; Class B, 1″ or less from base; Class C, 1″ to 5″ from base; Class D, 5″ to 20″ from base; Class E, 20″ or more from base.

whose position had to be recorded at each low tide, only a cursory glance at each limpet was possible. As mentioned above we remained on the top of Sand Rocks during the high tide of June 16, 1939, from 10 a.m. until 2 p.m. The tide was +4.3 feet by the tide books, but a strong westerly wind increased it so that it approached +5 feet. The smaller individuals of both *A. scabra* and *A. digitalis* moved as soon as they were splashed by the incoming tide, and continued to be active as long as the tide covered them. The larger specimens, both marked and unmarked, remained in their positions and showed no signs of activity. Particular attention was paid at this time to members of Group IV, 13 of whose 15 members had not been observed away from their bases during the weeks of observation, but none was observed to move.

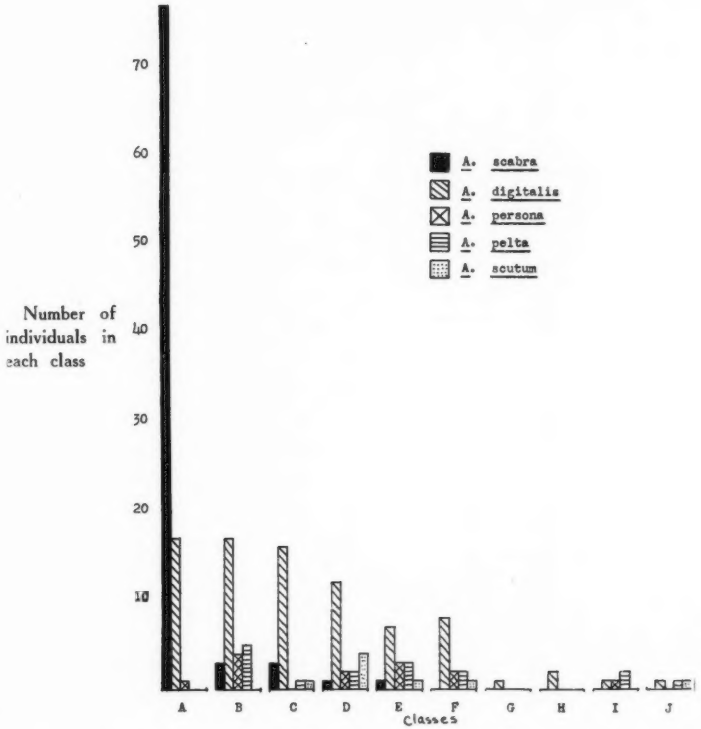

Fig. 3. Total observed movement, individuals arranged in classes. Class A, no movement; Class B, 0″-10″; Class C, 10″-20″; Class D, 20″-35″; Class E, 35″-50″; Class F, 50″-70″; Class G, 70″-90″; Class H, 90″-120″; Class I, 120″-150″ Class J, 150″ or more.

We were impressed by the apparent disregard with which the moving limpets treated the matter of wave shock, no matter how strong. In both species the shell was lifted well off the substrate and the margins exposed to the action of the strong wind-driven waves, but the limpets were not dislodged.

Records were made of the paths of two of the more active *A. scabra* by mapping their positions at short intervals. These appear in figure 5. Both individuals were at all times exposed to the maximum shearing wave action, a type most likely to dislodge them. Their movements did not seem to indicate a search for protection and were probably too rapid to permit of feeding; the objective may have been more favorable feeding grounds. The fact that the second *A. scabra* stopped in one place for a considerable period bears out this hypothesis.

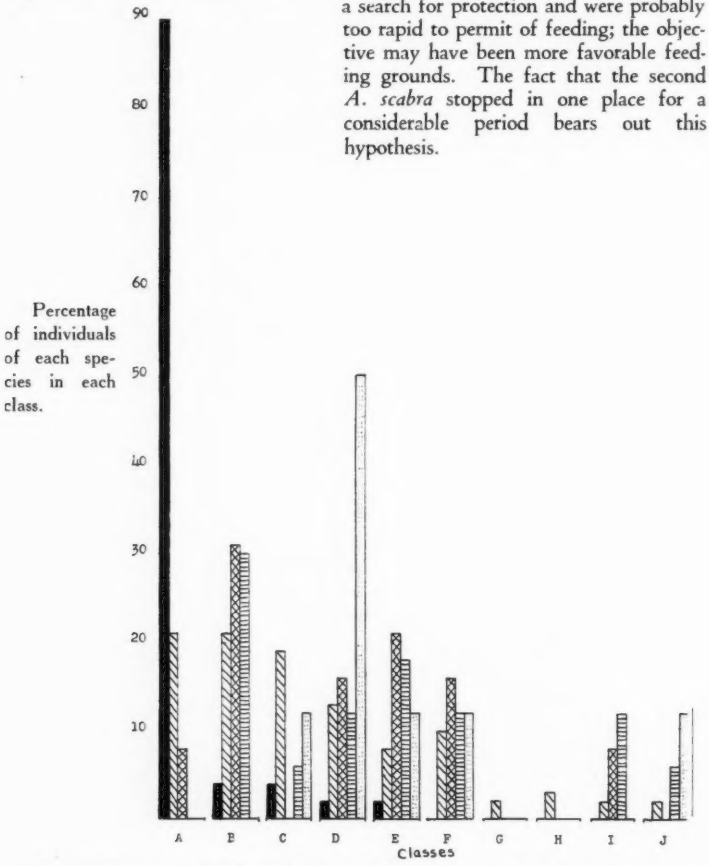

Fig. 4. Percentage of individuals of each species in each class of total movement. Symbols and classes as in fig. 3.

Figs. 5-14. Graphs showing movements of individual limpets. The ringed dot "B" is the marked base. The numbered points indicate positions of limpets at subsequent observations. Asterisks indicate that the limpet's base was occupied by some other limpet at that observation.

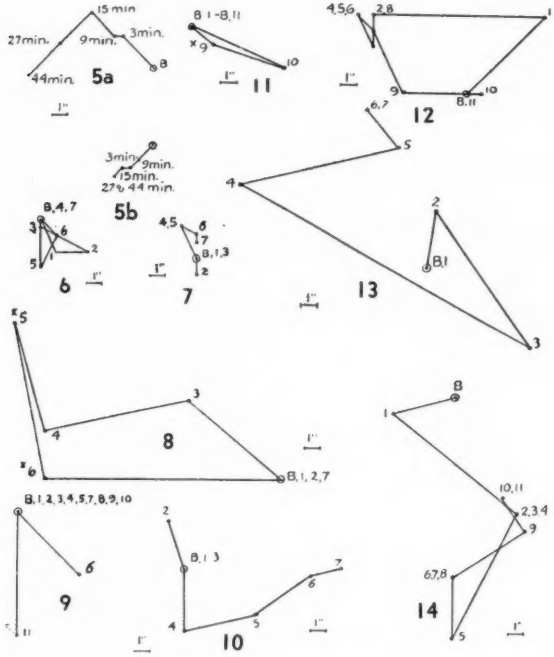

Fig. 5a and b. Records of actual movement of two *A. scabra* when covered by water.

Fig. 6. Group X, No. 10. *A. digitalis.*
Returned from ..... 1½″
Greatest distance ..... 4″
Total distance ..... 17″

Fig. 7. Group X, No. 7. *A. digitalis.*
Returned from ..... 1″
Greatest distance ..... 2″
Total distance ..... 5″

Fig. 8. Group X, No. 22. *A. digitalis.*
Returned from ..... 15″
Greatest distance ..... 20″
Total distance ..... 51″
* Base occupied by another limpet at this time.

Fig. 9. Group XII, No. 5. *A. digitalis.*
Returned from ..... 6″
Greatest distance ..... 8″
Total distance ..... 20″

Fig. 10. Group X, No. 6. *A. digitalis.*
Returned from ..... 3″
Greatest distance ..... 10″
Total distance ..... 21″

Fig. 11. Group I, No. 14. *A. scabra* returned to base.
Returned from ..... 6½″

Greatest distance ..... 6½″
Total distance ..... 15″

Fig. 12. Group II, No. 20. *A. pelta* returned to base.
Returned from ..... 1″
Greatest distance ..... 8½″
Total distance ..... 36″

Fig. 13. Group XI, No. 8. *A. digitalis* not returned.
Greatest distance ..... 26″
Total distance ..... 97″

Fig. 14. Group II, No. 25. *A. scabra.*
Greatest distance ..... 14″
Total distance ..... 35″

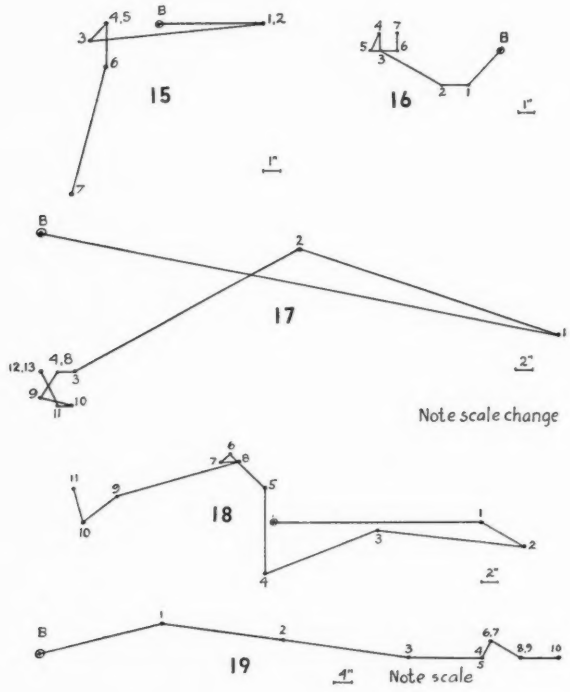

Fig. 15. Group IX, No. 9. *A. scabra.*
Greatest distance ..... 10″
Total distance ..... 29″

Fig. 16. Group X, No. 15. *A. digitalis.*
Greatest distance ..... 7½″
Total distance ..... 16″

Fig. 17. Group XII, No. 14. *A. digitalis.*
Greatest distance ..... 62″
Total distance ..... 135″

Fig. 18. Group II, No. 21. *A. persona.*
Greatest distance ..... 23″
Total distance ..... 121″

Fig. 19. Group VI, No. 3. *A. persona.*
Greatest distance ..... 120″
Total distance ..... 125″

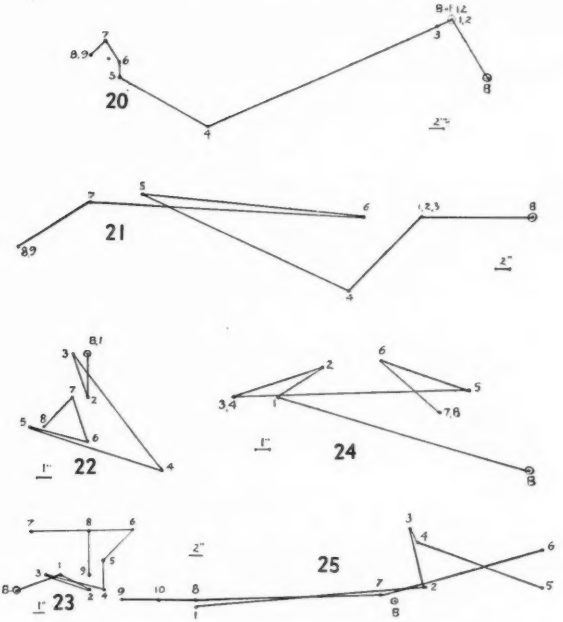

Fig. 20. Group VI, No. 11. *A. persona.*
Greatest distance .....54″
Total distance .....62″

Fig. 21. Group VII, No. 15. *A. pelta.*
Greatest distance .....75″
Total distance .....143″

Fig. 22. Group IX, No. 12. *A. pelta.*
Greatest distance .....8″
Total distance .....36″

Fig. 23. Group VIII, No. 6 *A. scutum.*
Greatest distance .....6″
Total distance .....31″

Fig. 24. Group VIII, No. 20. *A. scutum.*
Greatest distance .....20″
Total distance .....56″

Fig. 25. Group VI, No. 7. *A. scutum.*
Greatest distance .....37″
Total distance .....150″

Conclusions

No evidence of any behavior pattern which can be called a homing instinct was found in this study of *Acmaea,* and until a similar statistical study is made of *Patella,* no conclusions with regard to homing in that form can be made. *A. persona, A. pelta, A. scutum,* and *A. digitalis* show no tendency to return home. *A. scabra,* although showing no observable tendency to return to any given spot, did show a great tendency to remain in the same place for long periods of time. It is conceivable, but hardly probable, that all these *A. scabra* could get out of their pits and back into them so exactly as not to be detected. There is no positive evidence that the *A. scabra* did not leave their

pits except that in some cases the fingernail polish which marked the anterior and posterior edges of the shell dried to form a seal between the shell and substrate and remained unbroken. Hewatt (in press) and Shapovalov (private communication) working at the Hopkins Marine Laboratory at Pacific Grove, California, do report observations of homing behavior in *A. scabra*. In both instances the environmental conditions (substrate, presence of pits, amount of algal growth, height above mean lower low tide, etc.) were quite different from those obtaining at Moss Beach and this may explain the difference in the observed behavior.

In general, it seemed to us to be purely a matter of chance whether an animal returned to its marked base or to some secondary location. Some few animals, seventeen, were found to leave their base and move to some other location, at which they remained for a considerable length of time. We realize, of course, that if the limpets do have a home to which they usually return the marked base is not necessarily this home and that it is entirely possible that the animal was away from the most desirable location in its immediate vicinity when the marking was done. Even when these doubtful cases of returns are added to the known returns the total is not sufficient to be statistically significant.

A comparison of the activity of groups on different substrates and under varying physical conditions seems to indicate that specific differences may be as important in determining activity as are environmental factors; for example, *A. scabra*, whether high and scarcely ever covered with water or low and frequently covered, tend to remain in one position.

To summarize, it may be said that *A. scabra* may have homes but our observations show no homing instinct. By "homes" is meant certain vantage points on the substrate surface more desirable than others because of more adequate protection, greater abundance of food, or other reasons, physical or biotic. Young *A. scabra* move around and feed presumably to satisfy their greater food requirements. They sometimes settle for a time into small depressions in the rock for protection or for feeding, but having left them, do not necessarily return. If the animal returns to the same spot it is purely a matter of chance, since it moves about in a relatively small circumscribed area in which there are but a limited number of desirable locations. However, when *A. scabra* are older they appeared from our observations to settle in one place, moving from this only infrequently, if at all, presumably because they need less food since they are growing less rapidly. Under the conditions of our study in which they were sunk in deep pits in sandstone rock with a thick supply of alga present for food they may be able to get enough food from the area immediately beneath and around their shells. Or perhaps they have some kind of a plankton-feeding mechanism as has been found for a number of other sedentary molluscs. Adult animals may be said to have homes, their shells being curved to fit the pits or perhaps the pits being hollowed out by the combined action of the animal and waves to conform to the contour of the shell. This hypothesis agrees with our findings at high tide on Sand Rocks,

when small *A. scabra* were found to roam, whereas the larger specimens remained in their pits.

A. digitalis, on the other hand, seem to be "home renters" rather than "home owners," for they move considerably more than do *A. scabra,* only about 20 percent of them being found constantly in one location. It was among the groups of *A. digitalis* that most of the replacements took place; as one animal moved out another moved into its location. In this species, too, the small individuals were seen to move more than the large ones during high tide.

The only conclusion that can be drawn safely from such small numbers as those of the *persona-pelta-scutum* group is that there is an amount of variability in movement within each species. None of the individuals of the *A. scutum* or *A. pelta* group, and only one of the *A. persona* group, stayed in one place. The remaining individuals varied greatly in the total distances which they covered.

Summary

1. *Acmaea* of five species, *digitalis* (formerly *persona*), *scabra* (formerly *spectrum*), *persona, pelta,* and *scutum,* totalling 223 individuals, were marked and observed daily for two to three weeks and their changes in position recorded to determine whether or not they possessed a homing instinct.

2. No evidence of a homing instinct was found, since only 29 out of the 102 limpets known to have left their base returned to it subsequently.

3. The species were compared as to total minimum distance moved and greatest distance from marked base at any one time. Graphs are presented making these comparisons.

4. Significant differences between the species were found. *A. digitalis, A. persona, A. pelta,* and *A. scutum* gave no evidence of a homing behavior; *A. scabra* while showing no homing behavior, was observed to remain in one position for long periods of time. Hewatt, under other environmental conditions, has observed homing behavior in *A. scabra.*

5. Although no individuals were seen to move during low tide, at high tide both small *A. scabra* and small *A. digitalis* moved actively. The other species occupied positions too far under water at high tide for their movements to be observed. The paths of some moving *A. scabra* are included in graph form.

6. All but one of ten individuals of a group of *A. scabra* forcibly removed from their pits failed to return.

7. The data indicate that limpets of the genus *Acmaea* do not possess a homing instinct. However, it is believed that some, particularly the older individuals of *A. scabra,* possess homes, that is, locations most desirable from the standpoint of protection and available food, to which return after leaving is purely a matter of chance.

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Observations on the Homing Limpet, Acmaea scabra Gould

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The limpets have created a great deal of interest among naturalists because of the homing habit which is exhibited to a marked degree by certain members of the group. Extensive observations on *Patella vulgata* L., the common limpet of the Atlantic coast of Europe, have been made by J. H. Orton (1929) and by E. S. Russell (1907, 1909). Only two series of observations concerning the homing habit of members of the genus *Acmaea* have been recorded. Wilcox (1905) found no evidence of homing in the New England species, *A. testudinalis* (L.), while Wells (1917) obtained indefinite results in a brief study of *A. scabra* and *A. testudinalis*.

Of the seven species of *Acmaea* found in the Monterey Bay area, *A. scabra* occupies the highest zone on the rocks (Hewatt, 1935). It ranges through a fairly definite zone between the tide levels of two and six feet. In this connection it is interesting to note that the limpets of this locality comprise a number of species each of which is restricted to a relatively narrow vertical range; whereas, a single species, *Patella vulgata*, ranges practically throughout the entire intertidal of the coast of England (J. H. Orton, 1929, p. 279).

The shell margin of *A. scabra* is very irregular. When the animal is at rest on its "homing spot," the contour of the margin of the shell fits neatly into the irregularities of the rough granite surface to which the specimen adheres. Unlike *Patella*, these forms do not excavate a "sunken scar" in the rock surface (Davis and Fleure, 1903). During the absence of the animal, the "home" may be detected by its pale green color which may possibly be caused by the action of the excretions of the organism.

In order to determine the nature and extent of the homing habit in *Acmaea scabra*, the following observations and simple experiments were carried out on members of the group.

During a low tide interval on August 30, 1932, 31 specimens of this species, located in a selected area, were chosen for a detailed study. Of these, 26 were attached to a vertical rock face, located at a level approximately between 4.5 and 6.0 feet above mean lower low tide. The five remaining limpets were located on a horizontal surface which was thickly populated with rock barnacles except on the small areas covered by the limpets.

A number or letter was painted on the shell of each specimen and a white ring was made around its position on the rock surface. (A rapidly drying lacquer proved to be the most satisfactory material for marking purposes. The lacquer dried before the return of the tide and apparently had no effect

upon the movements of the animals. It was necessary to repeat the marking at various intervals.) The relative positions of the limpets were plotted on graph paper in order to detect any subsequent movements. The original locations of some of the specimens are shown in Fig. 1. (solid lines).

At 9:00 a.m. on the following day, during a period of high tide (5.6 feet), all of the limpets had moved from their marked areas. At 11:00 a.m. each one had returned "home," occupying its original position, exactly on the spot which had been marked on the preceding day.

On the next day the area was kept under continuous observation from the time the advancing water splashed over the marked animals until the tide had entirely receded. After the animals had been submerged several times by the oscillating water, they lifted their shells and started moving very slowly in various directions. The movements began at 8:45 a.m., and by 9:00 a.m. all of the marked limpets had moved away from their spots. Their movements were observed and recorded (Fig. 1, dotted lines). At 11:25 a.m. all of them had returned to their respective "homes." The courses which were taken by each limpet on leaving and returning "home" were apparently identical.

The excursions of the limpets were studied on four consecutive days. During this period, the limpets always retraced their trails when returning "home," but at the same time the general direction of the excursions always was changed from tide to tide.

In one high tide period, after limpet No. 3 had moved about four inches from its "home," as shown in Fig. 1, a shallow trench was chiseled out in the granite along the line AB. When the limpet reached the excavated area on its return, it settled down at the edge of the trench and remained until the next high tide advanced over the rock. During this period of high water, it went around the end of the trench and succeeded, perhaps by chance, in arriving at its "home."

On another occasion, one limpet, marked No. 15, had moved to a position nine inches above its homing spot. It was removed from the rock surface, taken into the laboratory at least 100 yards distance, where the rough margin of the shell was filed down until it would lie entirely in contact with a smooth, flat surface. The animal was then returned to the exact spot from which it was taken. As the water receded, the limpet returned to its homing spot and settled down in the exact position which it was known to have maintained during several days previous to this experiment. By the "exact position" is meant not only the exact homing spot but also the exact orientation on this spot. In the course of the next high tide it moved to a position approximately 21 inches away and it did not return to the homing spot, indicating that the fit of the shell to substratum was essential to its well being.

The movements of this individual were noted during the following days. After the fourth day it had taken up a new "home." At the end of 11 days the animal could not be found.

The results of this observation indicate that the limpets do not determine

their orientation on the homing spots by the "trial and error" method of fitting the shell into the surrounding rock surface. Furthermore, it indicates that the limpets do not "feel at ease" unless there is at least an approximate fit between the shell and the substratum, and that possibly the survival of the animal depends upon such a fit.

A granite boulder to which four specimens of *Acmaea scabra* were attached was brought into the laboratory and placed in a salt water aquarium. The water was allowed to run into the aquarium very slowly. The animals moved upward shortly after they became submerged and remained near the water surface for two and one-half hours. At the end of this time, the position of the rock was reversed in the aquarium so that the limpets were near the bottom. The water was then drained off and a slow stream of water was sprayed over the organisms. Three of the specimens returned to their original habitats on the rock after three hours. This indicated that the homing power is not dependent upon a geotropism or a sense of general direction.

Russell (1907, p. 856) has called attention to the fact that there is no agreement among the many observers in regard to the time at which the limpets make their excursions in search of food. It can be stated with certainty that, in the investigated area, specimens of *Acmaea scabra*, ranging in length from approximately 14 mm. to 30 mm., move away from their homing spots only when covered by the tide. Specimens under 14 mm. in length were noted to be moving about even during low tide periods; they did not remain on the same spot for a long period of time. The small forms are usually found at lower levels where the substratum is moist during most of the exposure periods.

In the case of *Patella vulgata*, Orton (1932, p. 7) found that two distinct growth forms exist. The shells from the higher and more strongly insolated intertidal areas were found to be higher and thicker. The individuals from the poorly insolated and moist areas were found to possess thin flattened shells. This also appears to be true in the case of *Acmaea scabra* but no quantitative work has been done to settle this question.

A more detailed and extended study of the homing habits of *A. scabra* should reveal some important facts concerning this interesting phenomenon.

An examination of the stomach contents of a large number of the limpets disclosed the presence of diatoms, encrusting and mat-forming algae, and small grains of granite which had been scraped from the rock surface.

A. scabra is dioecious and was found to be ovigerous from the latter part of August until the middle of January. Small specimens ranging from 2 to 5 mm. appear on the rocks during the winter months. Measurements taken in the month of July showed that the small limpets of the last spawning season had reached a size of 8 to 12 mm.

Of 465 individuals ranging between 20 and 30 mm. in length examined during the spawning season, 392 proved to be females. This greater pro-

portion of females may indicate a condition of protandry in this form. Orton (1928) has presented evidence to show that *Patella* is protandrous.

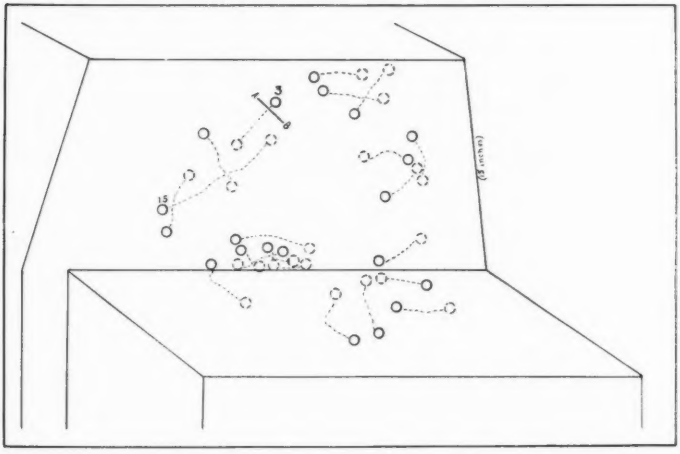

Fig. 1. Diagram showing the positions and movements of *Acmaea scabra* on vertical and horizontal rock surfaces of the upper littoral.

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Observations on Cooper's Hawk

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In the Osage Hills of Oklahoma (Osage County) May 13, 1936, the writer and Mr. Wallace Hughes while searching for a chat's nest discovered the nest of a Cooper's Hawk, *Accipiter cooperi* (Bonaparte), which contained four eggs. The structure was made of branches about the diameter of an ordinary lead pencil, contained a very shallow bowl whose floor was lined with bark, and was located about 30 feet high in the crotch of a post oak tree. No down was observed in the nest. A study of the habits of this bird was anticipated and a burlap blind was constructed on the ground about 20 feet from the tree containing the nest. In order to record accurate observations, a camera operated by ground controls, was placed in a green box situated approximately 6 feet above and to one side of the nest. The site was visited every 3 or 4 days during the study. The eggs hatched on the 30th and 32nd day after discovery. Two of them hatched on the earlier date and two on the latter date mentioned.

The parent birds displayed little fright but were extremely wary on visits to the nest and the immediate vicinity. Photographs of the female bird on the nest were secured with difficulty. She usually soared above while the male, which remained closer, was often seen darting among the trees at a distance of about 100 feet from the nest. The male was not observed to visit the nest nor to feed the young during the study. This may have been due to the writer's presence and/or the blind. Observations on food brought to the young included the hind leg of a rabbit, a young dickcissel, and portions of a meadowlark.

A few days after hatching, one of the young birds disappeared during a nocturnal storm. Six weeks later another was missing. The latter was thought to have taken flight. At this time the two remaining birds were taken to the writer's home for further observations. They became fairly tame and later when released would return to eat and could be handled freely and replaced in the cage. One of them died after four weeks under domestic conditions. The other one soon became wary and about a week later, after release, it failed to return for food but remained in the neighborhood for about two weeks. The captive pair preferred rats, mice, and birds to scraps of beef and pork. Before eating, the hawks always plucked their avian food and displayed unusual ability to remove feathers first from the feather tracts. Abdominal viscera were invariably the first parts of the carcasses to be ingested.

With reference to the incubation period of eggs of this hawk, my observations indicate at least 30 or 32 days, whereas Sumner (1929) recorded about

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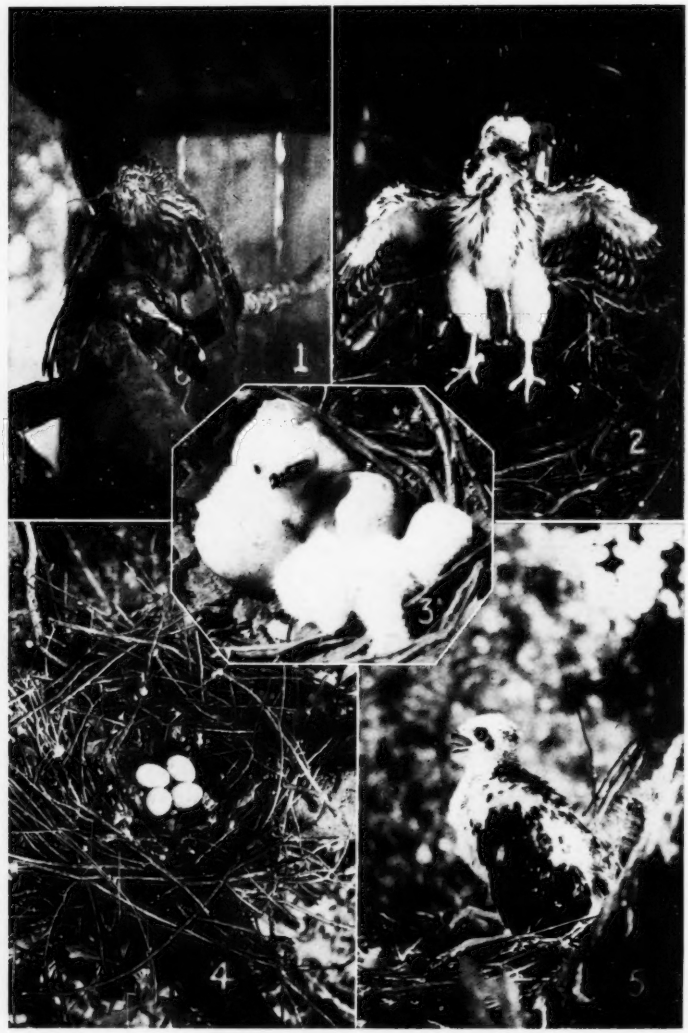

Fig. 1. Preadult at 13 weeks of age; Fig. 2. Young hawk at 6 weeks of age; Fig. 3. Newly hatched young and eggs; Fig. 4. Nest immediately after discovery; Fig. 5. Young hawk at 5 weeks of age.

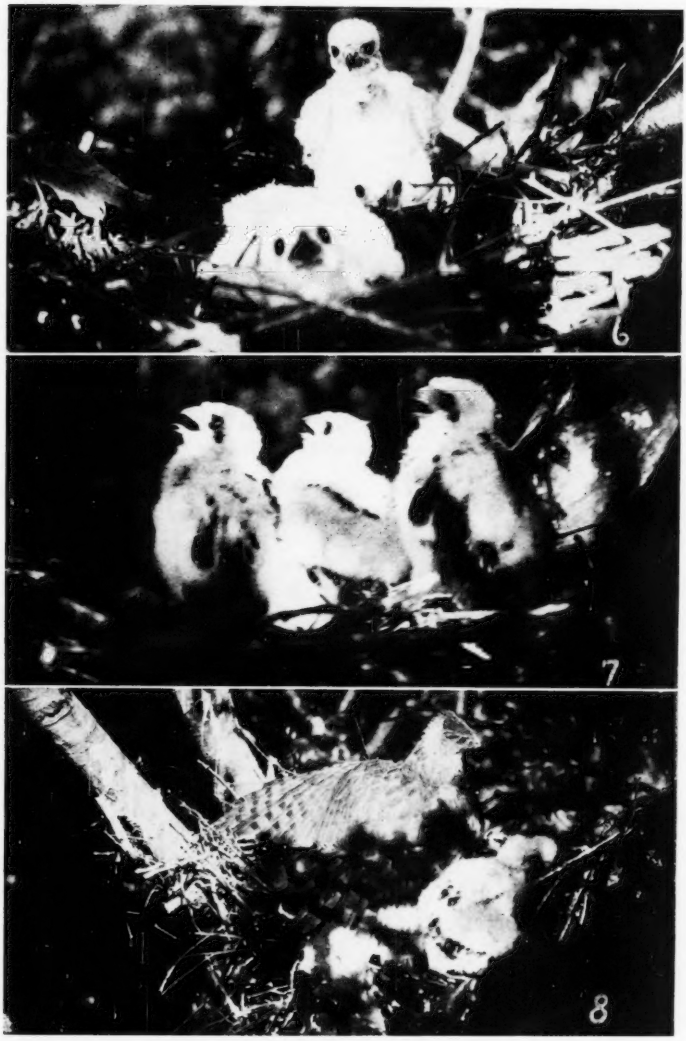

Fig. 6. Young birds at 3 weeks of age; Fig. 7. Young birds at 4½ weeks of age; Fig. 8. Female bird on nest.

24 days. This author, however, observed that the eggs hatched 24 days after discovery, at which time the eggs appeared freshly laid. Bent (1937) records that the incubation "is said to last twenty-four days." In that eggs of this species are usually laid one to two days apart (Bent, 1937), it is possible that some of the eggs observed by Sumner were at least two or more days old when discovered. The period of incubation for marsh hawk, *Circus hudsonius* (Linnaeus), eggs has been variously estimated as 21 to 31 days (Bent, 1937). This indicates difficulties encountered in the determination of this type of data under natural conditions, or that possibly there is a variation in this stage of the life history of some of the birds of prey. The normal number of eggs for Cooper's hawk is 3 to 6 per clutch (Pearson et al., 1936). Sumner (1929) observed hatching of 5 of a clutch of 6 eggs and Bent, 2 of 4 eggs laid. In the latter case, however, one of the eggs disappeared and another was addled. The condition of the latter was apparently caused by its displacement in the fabric of the nest. Four eggs (Fig. 4) were observed in the present study and hatching was 100 per cent. Present observations on the behavior of the parent birds and location and construction of the nest, compare favorably with those of Bent (1937) and Sumner (1929), however, the male bird in this study was observed neither to feed the young nor to incubate the eggs. Although Bent found that the nest was relined with fresh green sprigs of pine after the eggs hatched, no green material was used in this manner during my observations which were done in a deciduous area. The young, in this work, began leaving the nest at the age of six weeks (Fig. 2) which is about one week later than that observed by Bent. It is interesting to note that my observations indicate a longer incubation period and slower development of the young than previously recorded by Sumner and Bent.

Contributions of this paper may be listed as (1) a longer record of incubation, (2) information on food consumed by nestlings of this species, (3) a record of later departure of young from the nest, (4) feeding behavior of preadults, (5) general behavior of young Cooper's hawks under cage conditions, and (6) minor variations in the behavior of the parent birds.

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The Land Mammals of Nova Scotia*

Ronald Ward Smith

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Introduction

The first comprehensive accounts of the mammals of Nova Scotia were by J. Bernard Gilpin whose findings were published in the period 1867 to 1874. Indeed, up until now no one else seems to have attempted to list all of the different species inhabiting the Province and scarcely anything was published after Gilpin's time until the "nineties" of the last century when Outram Bangs interested himself in the fauna of eastern Canada. Then, he named, as new, five kinds of mammals from Nova Scotia.

About this same time, C. H. Goldthwaite also collected some material in the Province. In 1907 Harold F. Tufts and Wilfred H. Osgood collected mammals in Nova Scotia. Then for more than fifteen years little or no collecting was done. But, in 1924, Rudolph M. Anderson and C. H. Young of the National Museum of Canada made extensive collections on Cape Breton Island and in southwestern Nova Scotia. Young returned the following year and collected in Annapolis County.

Since 1925 there has been renewed interest in the mammalian fauna of the Province. Austin L. Rand collected in Kings and Annapolis counties at various times from 1925 to 1931, and in 1928, R. M. Anderson took additional specimens from Cape Breton Island. Victor E. Gould also collected specimens in Kings County from 1927 to 1935. In 1930 Morris M. Green made a splendid collection of the smaller mammals from Queens and Digby counties. Several years later, in 1933, Carolyn Sheldon collected in the Lake Kedgema-

* Contribution from the California Museum of Vertebrate Zoology.

kooge region in Queens and Annapolis counties. The following year, A. Brazier Howell collected for a brief period in the Margaree district of Inverness County. In the late summer and autumn of 1935, Victor E. Gould and W. Earl Godfrey collected in various parts of Cape Breton Island and Guysborough County for the National Museum of Canada, and from 1935 to 1938, I collected in Pictou, Hants, Kings, and Annapolis counties.

In the present paper an attempt has been made to bring together all the data obtainable, published or otherwise, which pertains to the distribution and taxonomy of the land mammals of the Province. The collections in the California Museum of Vertebrate Zoology, National Museum of Canada, Royal Ontario Museum of Zoology, Museum of Comparative Zoology, and Museum of Zoology of the University of Michigan, have importantly supplemented the published data used.

To those in charge of these collections I am grateful for the loan of specimens and acknowledge from Messrs. Rudolph M. Anderson, E. C. Cross, and Emmet T. Hooper, the receipt of critical information not otherwise obtainable. By virtue of the facilities provided at the California Museum of Vertebrate Zoology through Miss Annie M. Alexander, Mr. Seth B. Benson, Mr. E. Raymond Hall, and Mr. Alden H. Miller, I was enabled to bring my study to the present stage of completion. I am grateful also for Mr. Hall's critical assistance with the preparation of my manuscript, Mr. Morris M. Green's provision of important specimens, and for specimens from Cape Breton Island provided by Mr. A. Brazier Howell.

Physiography

The Province of Nova Scotia may be separated into three more or less distinct physiographical areas: (1) The southeastern mainland, (2) the northern mainland including that which borders the Bay of Fundy, Northumberland Strait, and the Minas Basin, and (3) Cape Breton Island.

The southeastern mainland, which is situated along the Atlantic seaboard, has a much diversified topography. Throughout this area are many hills, and valleys with lakes and swamps. The glacial deposits are heavy, and granite, slate, and quartzite are the typical rocks. On glacial deposits, where overdrainage has not occurred, a good growth of forest is found; otherwise these sections are usually barrenlands. The balsam fir *(Abies balsamea)* is the common tree on the summits of ridges, the slopes generally have a mixed growth, and the more nearly level sections and flats are usually grown up with hemlock *(Tsuga canadensis)* and two spruces *(Picea canadensis* and *P. rubra)*. The rocky southeastern coast extends for about two hundred and thirty-five miles, with many indentations and islands along its whole extent.

The northern mainland is considerably more diversified geologically, although topographically it is a much simpler formation than the southeastern part of the Province. Sandstones, limestones, conglomerates, and slates, as well as igneous and metamorphic rocks, are found here. The extent

of glacial deposit is small in this area. The forest types of the southeastern area are found here also, but there is a climax forest of deciduous trees and a generally more luxuriant forest growth.

Cape Breton Island may be divided into a northern and a southern part. The northern part is a plateau, rather higher than the rest of the Island, covered with a virgin forest of balsam fir and a small amount of red spruce and white birch *(Betula papyrifera)*. Muskegs are found in a continuous line on the summit of this plateau area and are overgrown with larch *(Larix laricina)* and black spruce *(Picea mariana)*. The southern part of Cape Breton Island has a more undulating terrain. Mixed growth and barrens predominate in this section.

The climate of Nova Scotia, although milder than that of any other province of Canada, is subject to extremes of heat and cold and the changes in temperature are rapid. The average temperature for the summer is 65 degrees Fahrenheit, with an average winter temperature of 25 degrees F. The temperature within one year may range from 96 degrees above zero to 32 degrees below, with changes of as much as 50 degrees or more in a day. Normal conditions of temperature are somewhat altered on or near the seacoast; there fogs, which are of frequent occurrence, lower the high temperature in summer and the severity of winter is mitigated by southerly winds, which blow in from across the Gulf Stream.

Spring is generally a short and chilly season, with the transition to summer often rapid. The autumn is pleasant and even after snow falls in early November, mild weather is usually prevalent for several weeks.

Factors Influencing Distribution of Mammals

The Province of Nova Scotia, which in outline is roughly the shape of a long, narrow peninsula, is nearly detached from the mainland. It is bordered on the west by the Bay of Fundy and is connected with New Brunswick by a low neck of land only 15 miles wide. On the north it is bordered by Northumberland Strait and the Gulf of St. Lawrence, and on the south and east by the Atlantic Ocean.

Nova Scotia, then, is almost an island, and the effect of this relative isolation is reflected in the fauna of land mammals. Several species have developed insular races limited to Nova Scotia. Several species that occur farther north in the coniferous forests find their southern limit of range in Nova Scotia, and several species of generally more southern distribution reach their limit of northern range in this peninsula.

Nova Scotia is a part of the now partly submerged, Atlantic upland region which in early geologic time connected the highlands of New Brunswick, Nova Scotia, Newfoundland, and Labrador. Since the last glacial epoch, when the entire region was affected, the outline of the Province has varied slightly depending upon earth movement. The general effect has been farther submergence. This is evidenced by the numerous drowned forests on the beaches of the Bay of Fundy. Thus, it appears that the Province has become more nearly surrounded by water since the postglacial period, and it may be

that morphological differentiation in several species has been aided or hastened by the isolation of the populations inhabiting this peninsula.

The distribution of mammals in Nova Scotia, it seems to me, is determined by the availability of habitats and ecologic niches. Moisture and temperature appear to be secondary in importance as factors limiting distribution, although they directly display great effect on the habitats through vegetation and soil conditions.

The great uniformity of the vegetation and physical conditions in this low coastal region seem to be paralleled by a uniformity in the mammalian fauna. Species which range widely in the Province show strong racial homogeneity, and no species which ranges thus has as many as two subspecies in the Province.

Faunal Relationships and the Biotic Province

Of the forty-five kinds of land mammals known from Nova Scotia, five have been introduced, and three are considered to be extinct or nearly so. Of the remaining species, thirteen are of races apparently restricted to Nova Scotia. Species occurring in adjacent parts of eastern Canada and New England, which, so far as is known, are not found in Nova Scotia, are as follows: *Parascalops breweri, Sorex gaspensis, Lasionycteris noctivagans, Lasiurus borealis, Mustela rixosa, Mustela frenata, Gulo luscus, Taxidea taxus, Urocyon cinereoargenteus, Synaptomys borealis, Microtus chrotorrhinus,* and *Sylvilagus transitionalis.* The fauna of Nova Scotia is composed of fewer species than the fauna of the adjacent, continental part of North America but is considerably richer than that of Newfoundland.

Canadian Biotic Province.—All of Nova Scotia lies within this Biotic Province which extends outside of Nova Scotia, over New England, southern Quebec and Ontario, and parts of the western Great Lakes region. This name was proposed by Dice (1938) in a paper which referred especially to mammals. Florally, this Province is characterized by a climax forest of hardwoods, of which the yellow birch *(Betula lutea)* and the sugar maple *(Acer saccharum)* are the dominant trees. Occurring frequently in this climax forest are the eastern hemlock *(Tsuga canadensis)* and the white pine *(Pinus strobus).* Subclimax forests of this region, because of different edaphic and climatic conditions, are characterized by pines, spruces, and tamaracks.

In Nova Scotia, two sub-districts of the Canadian Biotic Province seem worthy of recognition. These may be known as: (1) The Atlantic Upland. and (2) the Acadian Plain.

THE ATLANTIC UPLAND

This area, in Nova Scotia, includes the areas that several zoogeographers have marked as the Canadian Life-zone of the Province. It occurs all through the southeastern section and includes most of Cape Breton Island. Topographically this area is relatively high, with a gradual slope toward the Atlantic Ocean. The heavy glacial deposit has resulted in poor drainage, and lakes, "stillwaters" and muskegs are abundant. The climate is relatively humid; there is much fog and rain. This area has a considerable growth of sub-

climax conifers, and muskegs are present where edaphic conditions prohibit the growth of the hardwood climax forest.

Mammals typical of this area, or found there more often than elsewhere, are: Red squirrel, varying hare, Canada lynx, moose, porcupine, caribou, American marten, fisher, deer mouse, beaver, and woodland jumping mouse. Associated with this region are such birds as the white-throated sparrow *(Zonotrichia albicollis)*, pine grosbeak *(Pinicola enucleator)*, olive-backed thrush *(Hylocichla ustulata)*, spruce grouse *(Canachites canadensis)*, and Canada jay *(Perisoreus canadensis)*.

The Acadian Plain

This area comprises the low, northern and most fertile area, agriculturally, of Nova Scotia. Topographically it is low flat country, but is well drained by numerous rivers. Lakes are scarce in this district. The summer climate is warmer than in the upland area and the most luxuriant growth of hardwood forest occurs here.

Mammals, more or less restricted to this area, are: Raccoon, striped skunk, white-tailed deer, short-tailed shrew, wood mouse, and saddle-backed shrew. Birds typical of this area, in the breeding season, are the catbird *(Dumetella carolinensis)*, bobolink *(Dolichonyx orzivorous)*, rose-breasted grosbeak *(Hedymeles ludoviciana)*, and yellow warbler *(Dendroica aestiva)*.

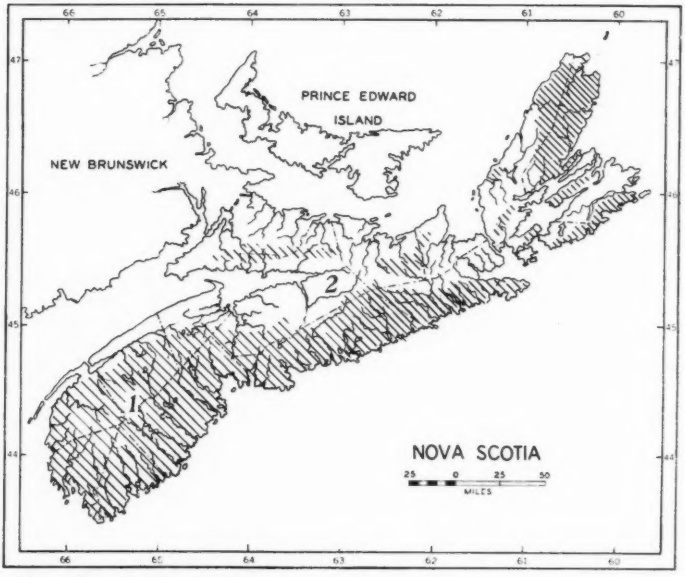

Fig. 1. Map showing the physiographic division in Nova Scotia. 1. Atlantic Upland. 2. Acadian Plain. Adapted from Goldthwait.

Accounts of Species

Class MAMMALIA, Mammals

Order INSECTIVORA, Insectivorous Mammals

Family TALPIDAE, Moles

Condylura cristata nigra subsp. nov.

Star-nosed Mole

Type.—Adult female, skin and skull; no. 86603, Mus. Vert. Zool.; Wolfville, Kings County, Nova Scotia; collected by Ronald W. Smith, November 13, 1937; original no. 1513.

Synonym.—*Condylura cristata*, Jackson, 1915:86.

Distribution.—Nova Scotia.

Diagnosis.—A race of *Condylura cristata* characterized by large size, dark color in winter pelage, large braincase, wide cranium, abruptly sloping forehead, wide rostrum, and large postpalatal process.

Measurements.—Selected measurements, in millimeters, of two males (nos. 86601 and 88602), and three females (nos. 86603, 86604, and 86608), from the type locality are, respectively, as follows: Total length, male, 207, 199; female, 197, 202, 194; length of tail, 87, 78; 77, 81, 73.7; hind foot, 30, 30; 28, 29, 29.4; condylobasal length, *33.9*, *34.2*; 32.9, —, —; palatal length, 14.5, 14.7; 14.4, 14.3, 14.1; cranial breadth, —, —; 13.5, 13.5, —; interorbital breadth, 7.3, 7.5; 7.4, —, —; maxillary breadth (across third molars), 8.2, 8.4; 8.1, —, 8.4; maxillary toothrow, 11.6, 11.9; 11.5, 11.7, 11.5 (measurements in italics are approximate).

Comparison.—Compared with *Condylura cristata cristata* from New Brunswick, Quebec, Ontario, Michigan, Pennsylvania, and New Jersey, *C. c. nigra* differs as follows: Cranial breadth and interorbital breadth slightly more, rostrum heavier, braincase larger and more rounded dorsally, forehead more abruptly sloping, postpalatal process larger, foramen magnum larger. In winter pelage *C. c. nigra* differs from *C. c. cristata* in being blackish rather than brownish dorsally and darker gray with less pale brown ventrally.

Remarks.—Usually this species is found in damp meadows and swamplands. Central parts of the Province have but little habitat suitable for star-nosed moles and it is not commonly found there. In most of the agricultural districts it is fairly common, and in years when it is abundant, it is numerous in the black muck soil of alder thickets and wet spruce forests.

One adult female, taken on May 8, 1938, at Wolfville, shows two areas of molt, one on the lower abdominal region and the other, in which the molt is equally as far advanced, on the pectoral region. Specimens taken in early November had acquired full winter pelage.

The underground tunnels of these moles are used also by *Blarina brevicauda* and *Sorex cinereus*. Several specimens of both of these shrews have been taken in traps set in mole runways eight inches below the ground. One star-nosed mole was caught in a *Microtus* runway in a wet, upland marsh. Often, in late winter, I have found mole tunnels in the snow and frozen slush above

ground. Several of these snow tunnels continued for over one hundred yards without entering the ground again.

Jackson (1915:90) noted differences between the star-nosed moles from Nova Scotia and those from other places but referred all of them at that time to *Condylura cristata cristata*. The noticeable color difference of specimens in fresh winter pelage, as well as the several differential cranial features, of the now more abundant material, from Nova Scotia, show the existence there of a well-marked geographic race.

*Records of Occurrence.**—Specimens examined, 21, as follows: *Antigonish County:* James River, 1 (Mus. Comp. Zool.). *Kings County:* Wolfville, 8. *Halifax County:* Halifax,1 (Mus. Comp. Zool.). *Digby County:* Digby, 11 (Mus. Comp. Zool.). Additional records: (Jackson, 1915:91): *Antigonish County:* James River, 1; *Hants County:* Newport, 2; *Halifax County:* Halifax, 7; *Digby County:* Digby, 18; *Shelburne County:* Barrington Passage, 1. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.) *Inverness County:* Frizzleton, 1; *Guysborough County:* East Roman Valley, 2. (E. C. Cross, in *Litt.*, Royal Ont. Mus. Zool.) *Inverness County:* Upper Margaree River, 3; *Kings County:* three miles east of Wolfville, 5. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.) *Kings County:* Canaan, 1; *Annapolis County:* South Milford, 4.

Family SORICIDAE, Shrews

Sorex cinereus acadicus Gilpin

Gray Shrew

Sorex acadicus Gilpin, Proc. and Trans. Nova Scotian Inst. Nat. Sci., 1 (pt. 2):2. 1867. Type from Nova Scotia.

Synonyms.—Sorex acadica Gilpin, 1870 (pt. 2):59. *Sorex platyrinus*, Gilpin, 1870 (pt. 2):59. *Sorex richardsonii*, Dobson, 1890, pt. 3, fasc. 1, pl. 23, fig. 9. *Sorex cinereus cinereus*, Jackson, 1928:49.

Distribution.—In Nova Scotia, occurs in all parts of the Province.

Remarks.—This race was described by Dr. J. Bernard Gilpin in his writings on the Mammalia of Nova Scotia, published in 1867. As was customary at that time, no type specimen or type locality more definite than Nova Scotia was indicated, although it is highly probable that the type locality is in the vicinity of Halifax, Halifax County. Study of a large series of the species *Sorex cinereus* from northeastern North America reveals that the form occurring in Nova Scotia, New Brunswick,and eastern Quebec, is distinguishable from other populations of the species *Sorex cinereus* by large size, long tail, wide cranium, large braincase, long and slightly arched toothrow, and long and slender rostrum. *Sorex acadicus* seems to be the earliest available name for this race.

Compared with specimens of *S. c. cinereus*, from Ontario, Manitoba, New York, Pennsylvania, Minnesota, Montana, and Connecticut, *Sorex cinereus acadicus* differs as follows: Braincase larger; maxillary toothrow longer and less arched; cranial breadth greater; condylobasal length greater; tail longer. From *Sorex cinereus miscix* from Labrador, *acadicus* differs in having pelage, in

* Specimens listed as examined unless otherwise indicated are in the California Museum of Vertebrate Zoology. In "Additional records" a source cited accounts for all records between the citation and the next period.

winter and summer, slightly darker; rostrum heavier and less tapering; and cranium less rounded laterally.

Average and extreme measurements, in millimeters, of a series of forty adult males and females from Kings, Digby, and Queens counties, Nova Scotia, are as follows: Total length, 103 (99-108); tail length, 45.5 (42-49); hind foot, 12.5 (12-13); condylobasal length, 16.5 (16.1-16.9); palatal length, 6.9 (6.7-7.2); cranial breadth, 7.9 (7.7-8.3); interorbital breadth, 3.0 (2.8-3.1); maxillary breadth, 4.3 (4.2-4.4); maxillary toothrow, 6.2 (6.0-6.4).

These shrews seem rather versatile in their choice of habitat, having been found in almost every type of locality in the Province, in marshes, swamps, meadows, fields, brushland, forests, and barrens. Rand (1933:44) says that in 1928 this species was one of the most common of the smaller mammals, though in 1931 he obtained only a single specimen from the same region where they were previously abundant. In 1936 I found this species to be numerous and in 1938 still more abundant in Nova Scotia.

Records of Occurrence.—Specimens examined, 60, as follows: *Kings County:* Wolfville, 42. *Digby County:* Maxwellton, 7. *Queens County:* Caledonia, 10. *Inverness County:* Northeast Margaree, 1. Additional records: (Jackson, 1928:49): *Inverness County:* Cheticamp Lake, 4; *Victoria County:* Barren, 1; Ingonish Centre, 1; *Antigonish County:* James River, 5; *Hants County:* Newport, 2; *Halifax County:* Halifax, 9; *Kings County*, 8; *Annapolis* or *Queens County:* Lake Kedgemakooge, 1; *Digby County:* Digby, 12; Brier Island, 1; Little River, Digby Neck, 3; *Shelburne County:* Barrington Passage, 23. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.) *Victoria County:* Cape North, 7; *Inverness County:* Frizzleton, 2. *Richmond County:* St. Peter's, 1; *Guysborough County:* East Roman Valley, 3. (E. C. Cross, in *Litt.*, Royal Ont. Mus. Zool.) *Inverness County:* Upper Margaree River, 4; *Kings County:* two miles east of Wolfville, 8. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.) *Annapolis County:* South Milford, 5; *Kings County:* Black River, 1; Forks River, 3.

Sorex arcticus maritimensis R. W. Smith
Saddle-backed Shrew

Sorex arcticus maritimensis R. W. Smith, Jour. Mamm., 20: 244-245. May 14, 1939. Type from Wolfville, Kings County, Nova Scotia.

Synonym.—*Sorex arcticus arcticus*, Jackson, 1928:68.

Distribution.—In Nova Scotia, known only from four localities on the mainland in the northern and western parts of the Province.

Remarks.—The most favored habitat in the Province for this species was the edges of freshwater swamps and marshes, which had become overgrown with tangled grass and rushes. It was obtained also under brush piles in dry orchard land, in runways of *Microtus*, inhabiting moss-grown swamps, and from damp ditch rows in a hayfield.

These saddle-backed shrews freely used the runways of *Microtus* and a number were caught in traps set for *Microtus*. *Microtus pennsylvanicus*, *Sorex cinereus*, *Blarina brevicauda*, and *Sorex arcticus* were often found living in the same habitat and using the same runways, although some runways of each of the four species mentioned above were found in which the other species did not occur. In situations where *Sorex arcticus* were trapped along with either *Microtus pennsylvanicus*, *Sorex cinereus* or with both, the *M. pennsylvanicus*

and *S. cinereus* were invariably caught first and in greater numbers. On April 18, 1938, at Wolfville, in one runway, apparently used exclusively by *Sorex arcticus*, eight specimens were trapped within a few hours in the early morning; three of the individuals were caught in one trap in a period of only five minutes.

One female, taken on May 3, 1938, at Wolfville, carried five large embryos. Another female, caught at Egerton, on July 10, 1938, was carrying seven half-formed young.

For many years, this species has been regarded as one of the rarest of small mammals known to occur in the northeastern part of the continent. In Nova Scotia it has been taken on only four occasions previous to 1936. The first was on July 6, 1920, when a single specimen was found dead on a lawn near Truro. The second animal was also found dead at the same locality on September 6, 1923. Both of these specimens are preserved as alcoholics in the Provincial Museum, at Halifax, Nova Scotia.

Twelve years later, in April, 1935, two specimens were trapped by V. E. Gould in the diggings of the star-nosed mole *(Condylura cristata)* in low, swampy ground at Grand Pré. He set many more traps in that same general locality but failed to take additional specimens.

On November 29, 1936, I collected an adult male in an upland swamp at Wolfville. Almost a year later, on October 9, 1937, another *Sorex arcticus* was trapped at the identical spot where the single specimen was taken in the previous year. In the spring of 1938, I obtained twenty-one specimens of this shrew at Wolfville and later in the summer collected nine more at Egerton.

Records of Occurrence.—Specimens examined, 30, as follows: *Pictou County:* Egerton, 9. *Kings County:* Wolfville, 21. Additional records: (Gould, 1936:103): *Colchester County:* Truro (1¾ miles east-southeast), 2; *Kings County:* Grand Pré, 2.

Sorex fumeus umbrosus Jackson
Smoky Shrew

Sorex fumeus umbrosus Jackson, Proc. Biol. Soc. Washington, 30:149. July 27, 1917. Type from James River, Antigonish County, Nova Scotia.

Synonym.—*Sorex fumeus* Miller, (1895:51).

Distribution.—In Nova Scotia, known to occur only throughout the mainland.

Remarks.—This species apparently ranges widely on the mainland of Nova Scotia. Although it probably occurs on Cape Breton Island, no specimens have yet been taken there.

The smoky shrew seems to prefer the moss-covered ground of hemlock forests in Nova Scotia, although I have taken it in spruce and deciduous forests as well. Within the Province, the species has been trapped in places as follows: Among the roots of ground juniper *(Juniperus communis)*, under decaying hemlock logs, in deep sphagnum moss in a spruce-fir association, under willow stumps on cultivated land, in runways of *Clethrionomys gapperi* in a moss-covered floor of a hemlock forest, and according to Rand (1933:44) in damp pastures and in the tunnels of *Condylura cristata*.

One adult female, in complete summer pelage, collected at Wolfville, on May 13, 1938, carried nine embryos in an early stage of development. One other female collected on May 10, 1938, was also in complete summer pelage. The other specimens taken from May 8 to 15, of the same year, showed no signs of molting from the winter coat.

Average and extreme measurements of a series of nineteen adult males and females from Kings, Queens, and Digby counties, are as follows: Total length, 116.8 (110-122); tail length, 46.8 (41.2-52.3); hind foot, 13.9 (13.0-15.0); condylobasal length, 18.4 (18.0-18.7); palatal length, 7.9 (7.8-8.0); cranial breadth, 9.0 (8.6-9.4); interorbital breadth, 3.8 (3.6-4.1); maxillary breadth, 5.3 (5.2-5.5); maxillary toothrow, 6.8 (6.7-6.9).

Records of Occurrence.—Specimens examined, 19, as follows: *Kings County:* Wolfville, 12. *Digby County:* Digby, 2; Maxwellton, 2. *Queens County:* Caledonia, 3. Additional records: (Jackson, 1928:66): *Antigonish County:* James River (type locality), 6; *Hants County:* Newport, 1; *Halifax County:* Halifax, 3; *Digby County:* Digby, 13; Little River, Digby Neck, 2; *Shelburne County:* Barrington Passage, 17. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Guysborough County:* East Roman Valley, 2.

Sorex palustris gloveralleni Jackson
Water Shrew

Sorex palustris gloveralleni Jackson, Jour. Mamm., 7:57, February 16, 1926. (Renaming of *Neosorex palustris acadicus* G. M. Allen, Proc. Biol. Soc. Washington, 28:15, February 12, 1915, not *Sorex acadicus* Gilpin, 1867). Type from Digby, Digby County, Nova Scotia.

Synonym.—*Sorex albibarbis*, Miller, 1895:46.

Distribution.—In Nova Scotia, found throughout the mainland. Probably occurs on Cape Breton Island but no records available from there.

Remarks.—This species has rarely been taken in the Province. I have trapped for it in many habitats which seemed suitable, but without success. Rand (1933:44) mentions taking it at pools of water in mossy coniferous woods, and among bushes growing between a second growth spruce association and a lakeshore. Sheldon (1936:209) caught several along the shore of a lake.

Records of Occurrence.—(Jackson, 1928:184): *Antigonish County:* James River, 1; *Halifax County:* Halifax, 4; *Kings County:* Aylesford, 1; *Digby County:* Digby (type locality), 5. (Rand, 1933:44): (*Annapolis County:* 16 miles south of Annapolis Royal?), 3. (Sheldon, 1936:209): *Queens County*(?): Beaver Lake, 2.

Microsorex hoyi thompsoni (Baird)
Pigmy Shrew

Sorex thompsoni Baird, Rept. Pacific R. R. Surv., 8(pt. 1, Mammals):34, 1857. Type from Burlington, Chittenden County, Vermont.

Synonyms.—*Sorex thomsoni*, Gilpin, 1867 (pt. 2):1; *Sorex hoyi*, Stone and Cram, 1902:187.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—This shrew is rare in Nova Scotia and the few specimens taken have come from widely separated places. I have taken only one, an adult female, at Wolfville, on April 30, 1938. It was trapped in the runway of a *Sorex* in deep sphagnum moss, from which, in the preceding three days, seven

Sorex cinereus were trapped. Gould (1936:103) records the taking of another *Microsorex* at Wolfville, in a rock pile on a dry hillside overgrown with wild apple trees and young conifers.

Measurements of two adult males from Maxwellton, are: Total length, 84, 80; tail length, 31.0, 30.5; hind foot, 10.5, 10.0. Skull measurements of one specimen from Maxwellton, which has the teeth moderately worn, are: Condylobasal length, 14.1; palatal length, 5.5; cranial breadth, 6.4; interorbital breadth, 3.0; maxillary breadth, 4.2; maxillary toothrow, 4.9.

Records of Occurrence.—Specimens examined, 3, as follows: *Kings County:* Wolfville, 1. *Digby County:* Maxwellton, 2. Additional records: (Jackson, 1928:205): *Victoria County:* Ingonish Centre, 1; *Halifax County:* 2; *Digby County:* Digby, 1, Little River, Digby Neck, 1. (Gould, 1936:103): *Kings County:* Wolfville, 1; *Queens County:* Caledonia. (Merriam, 1895:90): *Digby County:* Digby, 1. (Baird, 1857:35): *Halifax County:* Halifax, 1.

Blarina brevicauda pallida subsp. nov.

Short-tailed Shrew

Type.—Adult male, skin and skull; no. 86682, Mus. Vert. Zool.; Wolfville, Kings County, Nova Scotia; collected by Ronald W. Smith, October 5, 1937; original number, 1461.

Synonym.—*Blarina brevicauda*, Merriam, 1895:10.

Distribution.—Nova Scotia, eastern New Brunswick, and eastern Maine.

Diagnosis.—Similar to *Blarina brevicauda talpoides*, but averaging slightly larger, and in both winter and summer pelage, distinctly paler. Color in winter pelage: Gray of upper parts less blackish than in the subspecies *talpoides*. Upper parts pale fuscous mixed with brownish. Underparts pale grayish. Summer pelage similar to winter pelage. Skull: Indistinguishable from that of *B. b. talpoides*.

Measurements.—Average and extreme measurements, in millimeters, of a series of thirty adult males and females from western Nova Scotia, are as follows: Total length, 125.9(120.0-135.0); length of tail, 29.2 (24.0-33.0); hind foot, 15.8 (15.0-17.0); condylobasal length, 22.6 (22.0-23.4); palatal length, 10.1 (9.8-10.5); cranial breadth, 12.3 (12.0-13.0); interorbital breadth, 5.9 (5.7-6.1); maxillary breadth, 7.7 (7.4-8.1); maxillary toothrow, 8.6 (8.1-9.2).

Remarks.—Although not a strikingly differentiated race, specimens of *Blarina brevicauda pallida* from Nova Scotia are readily separable on basis of color from specimens of *B. b. talpoides* from eastern Quebec, Ontario, New York, Pennsylvania, and New Jersey.

In specimens from the Great Lakes region and the region eastward to the Atlantic seaboard, individual and local variations in the skulls are repeated at widely separated places and I have not found any constant cranial feature by which animals from Nova Scotia can be distinguished from specimens from farther to the southwest. The color in the Nova Scotian animal is distinctive; it is the palest representative of the *brevicauda* group.

Records of Occurrence.—Specimens examined, 39, as follows: *Inverness County:* Northeast Margaree, 3. *Antigonish County:* James River, 1 (Mus. Zool., Univ. Mich.).

Kings County: Wolfville, 19 (10 in Mus. Zool., Univ. Mich.). *Annapolis County:* Kedgemakooge, 14 (Mus. Zool., Univ. Mich.). *Queens County:* Caledonia, 1. *Digby County:* Maxwellton, 1. Additional records: (Rand, 1933:44): *Annapolis County:* (Fisher's Lake?), 8. (Sheldon, 1936:209): *Annapolis County?:* Lake Kedgemakooge. (Merriam, 1895: 13): *Digby County:* Digby, 8. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Victoria County:* Cape North, 9; *Inverness County:* Frizzleton, 4; *Richmond County:* St. Peter's, 1; *Guysborough County:* East Roman Valley, 16.

Order CHIROPTERA, Bats
Family VESPERTILIONIDAE, Common Bats
Myotis lucifugus lucifugus (LeConte)
Little Brown Bat

Vespertilio lucifugus LeConte, McMurtrie's Cuvier, Animal Kingdom, 1 (appendix): 431. 1831. Type from Georgia, probably the LeConte plantation near Riceboro, Liberty County.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—Of the three species of bats known to occur in Nova Scotia, this species appears to be the most abundant and widespread. The status and distribution of Nova Scotian bats is, however, not well known; *Eptesicus fuscus* and *Lasionycteris noctivagans* possibly occur in the Province, but as yet no records of these are available.

The little brown bat frequents buildings in various parts of the Province, and in one colony, living in an attic of an old farmhouse, at Mount Uniacke, several hundred individuals were found high up under the peak of the roof behind the broken wallsheathing, and in small spaces where the old, crumbling, brick chimney connected with the top of the roof. The owners of the building told me that large numbers of bats had lived in this attic during the early part of each summer for many years, that each June they were numerous, and that by the middle of August only a few remained.

This species, or Keen's little brown bat *(Myotis keenii septentrionalis)*, I have found clinging to rafters in deserted cabins in the central part of western Nova Scotia. In June, 1928, at Wolfville, I found ten adults and young, presumably of this species, inside a hollow spruce trunk in the day time.

Records of Occurence.—Specimens examined, 2, as follows: *Hants County:* Mount Uniacke, 1. *Kings County:* Wolfville, 1. Additional records: (Miller, 1897:62): *Halifax County:* Halifax, 1. (Miller and Allen, 1928:46): *Halifax County*, 41. (Rand, 1933:45): *Annapolis County:* 16 miles south of Annapolis Royal, 2. (Sheldon, 1936:210): *Annapolis* or *Queens County:* Lake Kedgemakooge. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Victoria County:* Cape North, 3.

Myotis keenii septentrionalis (Trouessart)
Keen's Little Brown Bat

Vespertilio gryphus var. *septentrionalis* Trouessart, Catal. Mamm. viv. et foss., p. 131. 1897. Type from Halifax, Halifax County, Nova Scotia.

Synonyms.—Northern form of *Vespertilio gryphus*, H. Allen, 1894:80; *Myotis subulatus subulatus*, Miller, 1924:72.

Distribution.—In Nova Scotia, known only from the western part of the Province.

Remarks.—This species has not been reported from more than a few localities in the Province, although probably it will be found in other areas of Nova Scotia. At Cheverie, on February 11, 1935, Gould (1936:103) found thirty-six in an old gypsum mine. The twelve examined as to sex were all males.

Records of Occurrence.—(Miller and Allen, 1928:107): *Halifax County:* Halifax, 2; *Annapolis County:* Annapolis, 1. (Gould, 1936:103): *Hants County:* Cheverie, 12. (Rand, 1933:45) (*Annapolis County:* 16 miles south of Annapolis Royal?), 1. (H. Allen, 1894:81) *Halifax County:* Halifax, 3.

Lasiurus cinereus (Beauvois)
Hoary Bat

Vespertilio cinereus (misspelled *linereus*) Beauvois, Catal. Raisonné Mus. Peale, Philadelphia, 1796:18 (p. 15 of English edition by Peale and Beauvois). Type from Philadelphia, Pennsylvania.

Synonym.—*Atalapha cinerea*, H. Allen, 1894:155.

Distribution.—In Nova Scotia, known only from Halifax, Halifax County.

Remarks.—This species is unquestionably rare in the Province and its inclusion in the Nova Scotia list rests on one specimen collected by J. B. Gilpin at Halifax (H. Allen, 1894:162).

Order CARNIVORA, Carnivorous Mammals
Family URSIDAE, Bears
Ursus americanus americanus Pallas
Black Bear

Ursus americanus Pallas, Spicilegia zoologica, fasc. 14, p. 5, 1780. Type from eastern North America.

Distribution.—In Nova Scotia, found commonly in the more unsettled parts of the Province.

Remarks.—Throughout the barren lands and forested areas, in the unsettled sections, bear sign is common, especially along the game trails of moose and deer. Bounties are paid on this species.

Records of Occurrence (Personal record of sign).—*Kings County:* Black River Lake. (Rand, 1933:45): *Kings County:* Aylesford; *Annapolis County:* 16 miles south of Annapolis Royal. (Sheldon, 1936:210) *Annapolis* or *Queens County:* Lake Kedgemakooge.

Family PROCYONIDAE, Raccoons and Allies
Procyon lotor lotor (Linnaeus)
Raccoon

[*Ursus*] *lotor* Linnaeus, Syst. Nat., ed. 10, 1:48, 1758. Type from eastern United States.

Distribution.—In Nova Scotia, throughout the mainland.

Remarks.—The raccoon is fairly common in the Annapolis Valley and is found occasionally in the interior of the Province. I have rarely met this animal in the field, but have often found its tracks along small streams in early winter in various districts in Kings County.

Gilpin (1870) reported the raccoon as moving into the Province in the

first part of the nineteenth century although he says that previous to that time it was reported unauthentically from Nova Scotia.

Records of Occurrence.—(Personal knowledge of occurrence). *Kings County:* Gaspereaux, White Rock, Port Williams, Kentville, New Minas. (Rand, 1933:45) *Annapolis County.*

Family MUSTELIDAE, Weasels and Allies

Martes americana americana (Turton)

American Marten

[*Mustela*] *americanus* Turton, Linnaeus, System of Nature, 1:60. 1806. Type from eastern North America.

Distribution.—In Nova Scotia, formerly found in all parts of the Province but now found only in restricted areas and even there but rarely.

Remarks.—The marten, in Nova Scotia, is now under rigid protection, and although approaching extinction may persist for some years in suitable habitat. In 1932 it was reported from the Liscomb Game Sanctuary in Guysborough County. Only the tracks of this species were seen, however, and no increase in its numbers have been noted there in recent years.

Martes pennanti pennanti (Erxleben)

Fisher

[*Mustela*] *pennanti* Erxleben, Syst. Regni Anim., 1:470. 1777. Type from eastern Canada.

Distribution.—In Nova Scotia, formerly throughout the Province; now probably extinct.

Remarks.—About 1865, as many as two hundred pelts of fishers were taken yearly by trappers according to Gilpin (1867), who even then mentioned it as headed for extinction. Since 1922 no reports of this species have been obtained.

Mustela cicognanii cicognanii Bonaparte

Short-tailed Weasel

M[*ustela*]. *Cigognanii* (sic) Bonaparte, Mag. (Charlesworth's) Nat. Hist., 2:37. January, 1838. Type from North America.

Synonyms.—*Putorius cicognanii*, Baird, 1857:163; *Putorius richardsonii*, Baird, 1857:164; *Mustela cigognanii cigognanii*, Rand, 1933:45.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—This species seems to prefer semi-open country where there are swampy areas, water courses, and brushy areas. Numbers of the short-tailed weasel fluctuate from year to year. In 1929 it was scarce in the Province along with most of the other fur-bearing animals. Gradually its numbers increased, and in 1934 and 1935, it was again fairly numerous. In 1936 it was also not uncommon, but in 1937 was again reported as scarce by many trappers.

Specimens have been examined in brown summer pelage, without any sign of molt, taken as late as November 16, although a skin taken on November 10 shows the beginning of the white winter pelage, and another specimen, obtained on November 11, is nearly half white. On January 2, 1935, at Wolfville, I collected two females. One is entirely white, except for the black

terminal tip of the tail, and the other is only half white. Another specimen, taken at Wolfville on January 10, is in complete winter pelage except for a few small patches of brown fur on the dorsal surface of the neck. I have trapped other weasels, not saved as study specimens, in complete winter pelage in the last week of November. It would appear that there is considerable variation in the time of acquiring the winter pelage.

Records of Occurrence.—Specimens examined, 22, unless otherwise indicated in the National Museum of Canada, as follows: *Victoria County:* Cape North, 2. *Inverness County:* Frizzleton, 3. *Richmond County:* St. Peter's, 1. *Guysborough County:* East Roman Valley, 5. *Kings County:* near Wolfville, 1; Wolfville, 5 (3 in Mus. Vert. Zool.). *Halifax County:* Hammonds Plains, 1 (U. S. Nat. Mus.). *Annapolis County:* Annapolis Royal, 1 (U. S. Nat. Mus.). *Digby County:* Digby, 3 (Mus. Comp. Zool.). Additional records: (Baird, 1857:166): *Halifax County:* Halifax, 1. (Rand, 1933:45): *(Annapolis County?).* (Sheldon, 1936:210) *Annapolis County.*

Mustela vison vison Schreber
Mink

Mustela vison Schreber, Säugthiere, pl. 127b. 1777. Type from eastern Canada.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—Mink are now fairly common in the interior of the Province where lakes and streams abound. In the report of the Department of Lands and Forests of Nova Scotia for 1929, few specimens were reported as taken by trappers that year. Since then there has been an increase in the annual number recorded as taken.

Lutra canadensis canadensis (Schreber)
Canadian Otter

Mustela lutra canadensis Schreber, Säugthiere, pl. 126b. 1776. Type from eastern Canada.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—The otter frequents the lakes and streams of the interior. A few years ago it was considered to be on the verge of extinction but more recently it has been reported to have slightly increased in numbers.

Mephitis mephitis mephitis (Schreber)
Striped Skunk

Viverra mephitis Schreber, Säugthiere, pl. 121. 1776. Type from eastern Canada.

Distribution.—In Nova Scotia, found throughout the mainland of the Province.

Remarks.—This species is most commonly found in the agricultural districts. It is fairly common in Annapolis Valley. The sparsely cultivated areas in the central part of Nova Scotia seem to limit it in distribution in these areas, since both Rand (1933:46) and Sheldon (1936:211) mention it as rare in the interior of western Nova Scotia. Rand *(op. cit.)* records that it has spread into the Province from New Brunswick, not having been found here before 1850.

Records of Occurrence.—Specimen examined, 1, from Wolfville, Kings County.

Additional records: (Rand, 1933:46): *Annapolis County*. (Sheldon, 1936:211): *Annapolis County*.

Family CANIDAE, Wolves and Foxes

Vulpes rubricosa rubricosa Bangs

Red Fox

Vulpes pennsylvanica rubricosa Bangs, Science, n. s., 7:272. February 25, 1898. (Renaming of *Vulpes pennsylvanica vafra* Bangs, Proc. Biol. Soc. Washington, 11:53, March 16, 1897, not *Vulpes vafer* Leidy, 1869). Type from Digby, Digby County, Nova Scotia.

Synonym.—*Vulpes fulvus rubricatus*, Miller, 1900:128.

Distribution.—In Nova Scotia, found in all parts of the Province.

Remarks.—In recent years, red foxes became uncommon in many sections of the Province, although in the central barren lands and vicinity thereof, it is still fairly numerous.

Records of Occurrence.—Specimen examined, 1, from Black River Lake, Kings County. Additional records: (Rand, 1933:46): *Annapolis County*. (Sheldon, 1936: 211):*Annapolis* or *Queens County:* Lake Kedgemakooge. (Bangs, 1897b:53): *Annapolis County:* Bear River; Annapolis; *Digby County:* Digby. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Inverness County:* Frizzleton, 6.

Alopex lagopus ungava (Merriam)

Arctic Fox

Vulpes lagopus ungava Merriam, Proc. Biol. Soc. Washington, 15:170. August 6, 1902. Type from Fort Chimo, Ungava, Quebec.

Distribution.—In Nova Scotia, of accidental occurrence.

Remarks.—The only record of the Arctic fox is one from Cape Breton Island. De Vany (1923:118) says, concerning it, "A white or Arctic Fox was shot at Lingan Bay, on the east coast of Cape Breton Island on April 10th, 1923, by William Ferrow and Neil Boutelier, residents of that district." Possibly it was an escaped caged animal, although it is conceivable that it reached Cape Breton by way of the ice-flows in the Gulf of St. Lawrence. I do not know what became of this specimen.

Canis lupus lycaon Schreber

Wolf

Canis lycaon Schreber, Säugthiere, pl. 89. 1775. Type from vicinity of Quebec, Quebec.

Distribution.—In Nova Scotia, formerly found throughout the Province. Now extinct.

Remarks.—There has been no record of a wolf in Nova Scotia for many years and since the beginning of the present century wolves probably have been extinct there.

Family FELIDAE, Cats and Allies

Lynx canadensis canadensis Kerr

Canada Lynx

Lynx canadensis Kerr, Anim. Kingd., vol. 1, systematic catalogue inserted between pages 32 and 33 (description, p. 157). 1792. Type from eastern Canada.

Synonym.—*Lynx gigas*, Rand, 1933:46.

Distribution.—In Nova Scotia, formerly throughout most of the Province; now extinct or exceedingly rare on the mainland but found still on Cape Breton Island.

Remarks.—The Canada lynx, apparently, has been decreasing in numbers during the last ten years and is thought by many to have been extirpated on the mainland. Much of the deep forest, the preferred habitat of this species, has been destroyed by fire and excessive cutting, and this has hastened its disappearance.

In 1864 (according to Rand, 1933:46, who quotes from Gilpin) it was more or less common throughout the Province and as many as two hundred and fifty skins were exported annually. By 1927, only about thirty-five pelts were sold. According to Sheldon (1936:211), this species was reported to have occurred around Lake Kedgemakooge. Records for the occurrence of this species, even for Cape Breton Island, are becoming fewer each year.

Lynx gigas Bangs
Bobcat

Lynx gigas Bangs, Proc. Biol. Soc. Washington, 11:50. March 16, 1897. Type from fifteen miles back of Bear River, Annapolis County, Nova Scotia.

Synonym.—*Lynx rufus rufus*, Rand, 1933:46.

Distribution.—In Nova Scotia, throughout the mainland in the more unsettled and wilder parts of the country.

Remarks.—Bobcats are not uncommon in Nova Scotia and numbers are trapped and shot each winter. I have found their dens in the interior of the country where apparently a number of individuals lived together. About these "cat ledges," as they are locally called, were found many remains of hares and spruce grouse. The dens were situated under huge granite boulders. Entrance to the dens was afforded by the crevices and fissures in the rocks. Bang's name *gigas* is used here in the form proposed by him. I have not satisfied myself about the distinctness, if any, from *Lynx rufus*. *L. gigas* may be only subspecifically distinct from *L. rufus*.

Records of Occurrence.—Specimen examined, 1, from Black River Lake, Kings County. Additional records: (Rand, 1933:46): *Annapolis County*. (Sheldon, 1936: 211): *Annapolis or Queens County:* Lake Kedgemakooge.

Order RODENTIA, Gnawing Mammals
Family SCIURIDAE, Squirrels, Marmots, and Chipmunks
Marmota monax canadensis (Erxleben)
Woodchuck

[*Glis*] *canadensis* Erxleben, Syst. Regni Anim., 1:363. 1777. Based primarily on the Quebec Marmot of Pennant. Type, therefore, from "Canada et ad fretum Hudsonis." Fixed by Howell (N. Am. Fauna, no. 377, p. 31. April 7, 1915) as Quebec, Quebec.

Distribution.—In Nova Scotia, throughout the mainland.

Remarks.—Woodchucks are fairly common in most of the agricultural sections of Nova Scotia. Their burrows are to be found in hay fields, along

railroad embankments, in orchards, pastures, small stands of second growth deciduous trees, and under old tumble-down buildings, and sometimes the animals live in piles of stones.

I have seen woodchucks in nearly all parts of the settled country except on Cape Breton Island. They may occur there but I have no evidence to show that they do.

Records of Occurrence.—(Sheldon, 1936:212): *Annapolis County:* Lake Kedgemakooge. (Rand, 1933:46): Annapolis Valley. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.): *Hants County:* Newport, 2.

Tamias striatus lysteri (Richardson)
Chipmunk

Sciurus (Tamias) lysteri Richardson, Fauna Boreali-Americana, 1:181. 1829. Type from Penetanguishene, Georgian Bay, Ontario.

Distribution.—The chipmunk is locally distributed in different parts of the Province wherever there are deciduous woods.

Records of Occurrence.—Specimens examined, 5, as follows: *Kings County:* Wolfville, 3. *Annapolis County:* Albany, 1. *Digby County:* Maxwellton, 1. Additional records: (Howell, 1929:19): *Antigonish County:* James River, 8; *Halifax County:* Halifax, 2; *Kings County*, 1; *Hants County:* Newport, 1; *Queens County:* Kedgemakooge, 1; *Digby County:* Digby, 15. (Sheldon, 1936:212): *Annapolis County.* (Rand, 1933:46): *Annapolis County.* (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.): *Annapolis County:* South Milford, 1; *Kings County:* Black River, 1. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Victoria County:* Cape North, 7; *Inverness County:* Frizzleton, 3; *Guysborough County:* East Roman Valley, 1.

Tamiasciurus hudsonicus gymnicus (Bangs)
Red Squirrel

Sciurus hudsonicus gymnicus Bangs, Proc. New England Zool. Club, 1:28. March 31, 1899. Type from Greenville, near Moosehead Lake, Piscataquis County, Maine.

Synonyms.—*Sciurus hudsonius*, Baird, 1857:271; *Sciurus hudsonicus*, Allen, 1898: 255.

Distribution.—In Nova Scotia, found throughout the forested areas of the Province.

The red squirrel usually is common and is generally distributed in Nova Scotia. Although mainly restricted to coniferous woods during the breeding season, in autumn and winter many live in hardwood areas, even in cultivated districts.

Besides the usual moss type of nest, these squirrels not infrequently use abandoned holes of flickers, and also old crows' nests. In late summer, red squirrels often are noisy in the forests, indulging in much calling, and chasing of one another. As winter approaches they become much less vociferous, and in the colder part of the year it is only on warm sunny days that they are heard.

Two adults, male and female, from Wolfville, were still in summer pelage on September 28 and October 5, respectively, and one adult male from Granville, had just commenced to molt on the shoulders and the middorsal line

on October 31. Specimens obtained on November 15 were in complete winter pelage. One adult male, on May 4, was still in worn winter coat.

Records of Occurrence.—Specimens examined, 15, as follows: *Cape Breton County:* Shenacadie, 1. *Kings County:* Wolfville, 13. *Annapolis County:* Granville, 1. Additional records: (Bangs, 1896:160): *Cape Breton County:* Shenacadie, 6; *Antigonish County:* James River, 1; *Annapolis County:* Granville, 4; *Digby County:* Digby, 16. (Allen, 1898:257): *Halifax County:* Halifax, 1. (Baird, 1857:271): *Halifax County:* Halifax, 2. (Rand, 1933:47): *Annapolis County:* (Fisher's Lake?); Trout Lake. (Sheldon, 1936:212): *Annapolis County:* Lake Kedgemakooge. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.): *Hants County:* Newport, 6; *Lunenburg County:* Lehave Bay, 2. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Victoria County:* Cape North, 6; *Inverness County:* Frizzleton, 4; *Richmond County:* St. Peter's, 5; *Guysborough County:* East Roman Valley, 4.

Sciurus carolinensis leucotis Gapper
Gray Squirrel

Sciurus leucotis Gapper, Zool. Journ., 5:206. 1830. Type from area between York and Lake Simcoe, Ontario.

Distribution.—In Nova Scotia, of irregular occurrence on the mainland.

Remarks.—The status of this species in Nova Scotia has not been satisfactorily determined at the present time. I have had several reports of these squirrels in the Province but possibly these were caged animals that had escaped. Rand (1933:47) mentions one from near Fisher's Lake, Annapolis County.

Glaucomys sabrinus macrotis (Mearns)
Flying Squirrel

Sciuropterus sabrinus macrotis Mearns, Proc. U. S. Nat. Mus., 21: 353. November 4, 1898. Type from Hunter Mountain, Catskill Mountains, Green County, New York.

Synonym.—*Sciuropterus sabrinus*, Bangs, 1896:162.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—On account of their nocturnal habits, flying squirrels are not often observed but are doubtlessly more abundant than is usually supposed. They were found in coniferous woods, in deciduous forests and in mixed growth.

From the middle of April until early in May I discovered a number of nests, in Kings County, by systematically going through wood lots and hitting the trunks of any stump that had either an old woodpecker nest or a hollow part near the top. If the hollow trunk was occupied by a flying squirrel, it would immediately scramble out. All nests found were composed of fine grasses and soft bark. In the winter these squirrels are not infrequently caught in traps set for carnivores in wooded regions.

Records of Occurrence.—Specimens examined, 4, as follows: *Kings County:* Wolfville, 3; Kentville, 1. Additional records: (Bangs, 1896:163): *Annapolis County:* Annapolis, 3; *Digby County:* Digby, 1. (Howell, 1918:37): *Annapolis County:* Annapolis, 3; *Halifax County:* Halifax, 3; *Kings County*, 5. (Rand, 1933:47): *Annapolis County:* Fisher's Lake, 1. (Sheldon, 1936:212): *Annapolis County:* Lake Kedgemakooge. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Inverness County:* Frizzleton, 3.

Family CASTORIDAE, Beavers
Castor canadensis canadensis Kuhl
American Beaver

Castor canadensis Kuhl. Beiträge z. Zoologie, p. 64. 1820. Type from Hudson Bay.

Distribution.—In Nova Scotia, throughout the western part of the Province.

Remarks.—The beaver formerly inhabited many of the lakes in probably all sections of the Province. About 1840 the species was nearly extirpated in Nova Scotia, but at the present time it is increasing and extending its range in the western part of the Province. In several of the lakes in Kings and Annapolis counties, large houses and much evidence of cutting were observed in 1938.

Family CRICETIDAE, Cricetid Rats and Mice
Peromyscus maniculatus abietorum Bangs
Deer Mouse

Peromyscus canadensis abietorum Bangs, Proc. Biol. Soc. Washington. 10:49. March 9, 1896. Type from James River, Antigonish County, Nova Scotia.

Distribution.—In Nova Scotia, found throughout the Province.

Remarks.—I collected this species only in hardwood forests of birch, maple, and beech. No specimens were taken in the subclimax forest of coniferous trees.

In examining a series of *Peromyscus maniculatus abietorum* from Nova Scotia, New Brunswick, and eastern Quebec, but little variation of any note was found although the Nova Scotian specimens averaged slightly larger in total length and tail length, and slightly shorter in maxillary toothrow than specimens from eastern Quebec and from along the boundary separating Maine from New Brunswick. The color of the pelage and cranial measurements were essentially the same.

Records of Occurrence.—Specimens examined, 5, as follows: *Inverness County:* Northeast Margaree, 1. *Kings County:* Wolfville, 2. *Digby County:* Maxwellton, 2. Additional records: (Osgood, 1909:46): *Antigonish County:* James River (type locality), 17; *Halifax County:* Halifax, 1; *Digby County:* Digby, 1. (E. C. Cross, in *Litt.*, Royal Ont. Mus. Zool.) *Inverness County:* Upper Margaree River, 1. (Rand, 1933:47): *Annapolis County:* Fisher's Lake. (Sheldon, 1936:213): *Queens* or *Annapolis County:* Lake Kedgemakooge. (R. M. Anderson, in Litt., Nat. Mus. Can.): *Victoria County:* Cape North, 7; *Inverness County:* Frizzleton, 1; Sea Wolf Island, 1; *Guysborough County:* East Roman Valley, 17.

Peromyscus leucopus caudatus R. W. Smith
Wood Mouse

Peromyscus maniculatus caudatus R. W. Smith, Proc. Biol. Soc. Washington, 52:157, October 11, 1939. Type from Wolfville, Kings County, Nova Scotia.

Synonym.—Peromyscus leucopus noveboracensis, Osgood, 1909:117.

Distribution.—Western Nova Scotia.

Remarks.—The wood mouse is found only in the western counties of the Province; it is the common species of *Peromyscus* occurring throughout the

settled areas there. At Wolfville, *P. l. caudatus* was caught most frequently in traps set near brush heaps, old stumps, in weedy fields and fence rows in small woodlots of conifers and hardwoods; also it was taken in marshy situations grown with *Juncus* and *Carex*.

Dice's (1939:1) paper, received after the above was written, gives important detailed information on the geographic variation of this mouse, including the population in Nova Scotia.

Records of Occurence.—Specimens examined, 29, as follows: *Kings County:* Wolfville, 19; one mile east of Wolfville, 9; two and one-half miles east of Wolfville, 1. Additional records: (Osgood, 1909:120): *Hants County:* Newport, 3. *Digby County:* Digby, 3. (Baird, 1857:462): *Halifax County:* Halifax, 3. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.): *Kings County:* Black River, 3; Wolfville, 4; *Annapolis County:* South Milford, 4.

Synaptomys cooperi cooperi Baird
Lemming Vole

S(ynaptomys) cooperi Baird, Mamm. N. Amer., p. 558. 1857. Type from unknown locality.

Distribution.—In Nova Scotia, apparently restricted in range to a few western counties in the Province.

Remarks.—In the spring of 1938 my attempts to obtain specimens of this species in Kings County were unsuccessful, although suitable habitats were trapped. Rand (1933:48) says that in 1928 he was unable to take any specimens of this species, although he found runways possibly made by lemming mice in certain sphagnum swamps. In 1931, after persistent trapping for ten days, he obtained three specimens. Sheldon (1936:213) found these voles to be scarce in Nova Scotia and after much effort, over a period of years, collected only three.

Records of Occurrence.—Specimen examined, 1, from Caledonia, Queens County. Additional records: (Howell, 1927:14): *Digby County:* Digby, 5. (Rand, 1933:48): *Annapolis County:* (Fisher's Lake), 3. (Sheldon, 1936:213): *Queens* or *Annapolis County:* Lake Kedgemakooge, 3. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.) *Annapolis County:* South Milford, 2.

Clethrionomys gapperi rufescens subsp. nov.
Red-backed Vole

Type.—Adult male, skin and skull; no. 86721, Mus. Vert. Zool.; Wolfville, Kings County, Nova Scotia; collected by Ronald W. Smith, May 7, 1938; original no. 1615.

Synonym.—Evotomys gapperi ochraceus Miller, 1894:193.

Distribution.—Nova Scotia.

Diagnosis.—A race of *Clethrionomys gapperi* characterized by pale color, heavy rostrum, flat cranium, and great cranial and interorbital breadth.

Comparison.—Compared with *Clethrionomys gapperi ochraceus* from New Brunswick, Maine, eastern Quebec, and Vermont, *rufescens* shows the following differences: Cranial and interorbital breadth slightly greater; rostrum heavier; braincase flatter; pelage paler throughout; dorsal area brighter and more sharply defined on dorsolateral margin.

Measurements.—Average and extreme measurements, in millimeters, of a series of fourteen adult males and females from Kings, Annapolis, Queens, and Digby counties, Nova Scotia, are as follows: Total length, 143.2 (133-155); tail length, 45.4 (41.5-51.5); hind foot, 19.0 (18.2-20.2); greatest length of skull, 23.6 (22.8-24.3); greatest width of skull, 13.2 (12.8-13.6); interorbital breadth, 4.1 (3.9-4.3); nasals, 6.9 (6.5-7.3); shelf of bony palate, 4.3 (4.2-4.5); palatine slits, 4.9 (4.7-5.3); postpalatal length, 9.8 (9.4-10.2); maxillary toothrow, 4.9 (4.7-5.1).

Remarks.—Bailey (1897:124) mentions that specimens from Digby and James River, Nova Scotia, showed a much brighter dorsal stripe than the type specimen of *ochraceus*, although he added no further comment on other characters of the Nova Scotian material.

Several specimens of *C. g. ochraceus* from New Brunswick indicate intergradation with *rufescens* in their pelage coloration. Specimens from eastern Quebec, Maine, and Vermont appear to be typical *ochraceus*.

In 1935, the red-backed vole seemed to be the commonest of all the small mammals in the Province. It was found commonly in hardwoods, coniferous forests, and barrens, as well as in partly cultivated areas. Members of a field party from the National Museum of Canada, collecting in eastern Nova Scotia in the late summer and early autumn of that year, told me that they found these voles somewhat of a nuisance when trapping for other small mammals, because these voles would invariably get into their traps before other kinds could be caught.

In the autumn of 1936, in Kings County, this species was apparently rare, since I caught only one specimen after about two weeks of persistent trapping in a hemlock forest which provides typical habitat for this vole.

No other specimen was taken until May, 1938, when eight adults were collected at Wolfville. These I trapped under hemlock slashings that were cut in the preceding winter. Here there was an old stand of hemlock, maple, and yellow birch. The forest floor was thickly covered with sphagnum moss, rocks, and old rotting stumps.

Two females, taken on May 9 and 10, 1938, in Kings County, carried five and six well-formed embryos, respectively. Another female, taken on July 30, of the same year, carried seven. Sheldon (1930:318) gives important data on this animal at Beaver Lake.

Records of Occurrence.—Specimens examined, 14, as follows: *Kings County:* Wolfville, 8. *Annapolis County:* Albany, 2. *Queens County:* Caledonia, 1. *Digby County:* Maxwellton, 3. Additional records: (Sheldon, 1936:213): *Queens* or *Annapolis County:* Lake Kedgemakooge. (Bailey, 1897:124): *Antigonish County:* James River; *Digby County:* Digby. (Baird, 1857:521): *Halifax County:* Halifax, 1. (E. C. Cross, in *Litt.*, Royal Ont. Mus. Zool.) *Inverness County:* Upper Margaree River, 1. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Victoria County:* Cape North, 13; *Inverness County:* Frizzleton, 7; *Richmond County:* St. Peter's, 5; *Guysborough County:* East Roman Valley, 48. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.): *Annapolis County:* South Milford, 5; *Kings County:* Black River Lake, 2.

Microtus pennsylvanicus acadicus Bangs
Meadow Vole

Microtus pennsylvanicus acadicus Bangs, Am. Nat., 31:239. March, 1897. Type from Digby, Digby County, Nova Scotia.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—This species is one of the commonest of the small mammals in the Province. It is to be found in many localities where grass, sedge, or moss is present in a degree sufficient to afford ample cover. It is most numerous in and about wet meadows and swamps. Here, in the growth of rank vegetation, other species, including *Blarina brevicauda, Sorex cinereus,* and *Sorex arcticus* use the runways of the *Microtus.* In years when these voles are abundant they may be found in dry, grassy upland, but normally the low, damp situations are the most favored.

In midwinter I have found places sheltered from the drifting snow and cold winds where one or more of these voles spent considerable time. From any one of these places several runways usually branched off in different directions. Piles of droppings, several inches in thickness, were sometimes found, but there was no indication of any nest structure. It occurred to me that these places, little platforms, may have been used by the mice to expose themselves to the warmth provided by sunshine, but I am not certain that they did so.

Specimens taken in the winter showed that females were pregnant in all the winter months except January.

Rand (1933:48) reported these voles as common in Annapolis County, in 1928, but in 1931, somewhat scarcer. Sheldon (1936:213) says that in 1933 there was a marked decrease in the numbers of these voles. In Kings County it was only fairly common in 1936 but was numerous there in 1938.

Records of Occurrence.—Specimens examined, 57, as follows: *Inverness County:* Northeast Margaree, 2. *Pictou County:* Egerton, 2. *Kings County:* Wolfville, 46. *Queens County:* Caledonia, 3. *Digby County:* Maxwellton, 4. Additional records (Rand, 1933:48): *Annapolis County:* (Fisher's Lake?). (Sheldon, 1936:213) *Annapolis* or *Queens County:* Lake Kedgemakooge. (Bailey, 1900:19) *Halifax County:* Halifax, 1. *Digby County:* Digby (type locality), 19. (E. C. Cross, in *Litt.*, Royal Ont. Mus. Zool.) *Inverness County:* Upper Margaree River, 1; *Kings County:* 2 and 3 miles east of Wolfville, 10. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.) *Victoria County:* Cape North, 16; *Inverness County:* Frizzleton, 3; *Guysborough County:* East Roman Valley, 4.

Ondatra zibethica zibethica (Linnaeus)
Muskrat

[*Castor*] *zibethicus* Linnaeus, Syst. Nat., ed. 12, 1:79. 1766. Type from eastern Canada.

Distribution.—In Nova Scotia, in suitable habitat throughout the Province.

Remarks.—This species occurs in many different habitats in Nova Scotia. Usually common in freshwater swamps and marshes, it is found also along tidal creeks and intervales in dyke and meadow country. In the interior of the Province it occurs along nearly all the water courses which have muddy banks and aquatic vegetation.

In large areas of marsh and swampland, houses frequently are found, although the usual type of den was a burrow in the bank of a creek or stream. The word creek, incidentally, in Nova Scotia, in the vernacular of the eastern seaboard, is a tidal stream; fresh water streams are either brooks or rivers. Little activity is noticeable after winter sets in, but following the frequent thaws, tracks of the muskrats are found in the frozen slush and snow near their dens.

Gilpin (1870:83) said that this species abounded in the Province and that at that time, eight to ten thousand skins were annually exported. These muskrats seem to thrive even under great persecution, as evidenced by the large numbers taken by the trappers each autumn.

Records of Occurrence.—Specimens examined, 5, all from Wolfville, Kings County. Additional records: (Rand, 1933:48): *Annapolis County.* (Sheldon, 1936:213): *Queens County:* Beaver Lake. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Victoria County:* Cape North, 3; *Richmond County:* St. Peter's, 2; *Guysborough County:* East Roman Valley, 1.

Family MURIDAE, Old World Rats and Mice

Rattus rattus rattus (Linnaeus)

Black Rat

[*Mus*] *rattus* Linnaeus, Syst. Nat., ed. 10, 1:61. 1758. Type from Upsala, Sweden.

Synonym.—*Mus rattus*, Gilpin, 1870:12.

Distribution.—Introduced in Nova Scotia; unknown at the present time.

Remarks.—Gilpin *(op. cit.)* mentions that this rat had become rare by 1869. I know of no records for it in recent years.

Rattus norvegicus norvegicus (Erxleben)

Norway Rat

[*Mus*] *norvegicus* Erxleben, Syst. Regni Anim., 1:381. 1777. Type from Norway.

Distribution.—Introduced in Nova Scotia; found almost everywhere in the settled districts of the Province.

Remarks.—In many sections of Nova Scotia these rats have taken to living in fields and marshlands, but they are most frequently encountered in towns and cities. Aside from house mice *(Mus musculus)*, they are the most abundant non-indigenous mammals in the Province.

Mus musculus Linnaeus, subsp.?

House Mouse

[*Mus*] *musculus* Linnaeus, Syst. Nat., ed. 10, 1:62. 1758. Type from Upsala, Sweden.

Distribution.—Introduced in Nova Scotia; found practically throughout the Province.

Remarks.—This mouse is common in nearly all the settled districts of Nova Scotia. It is now found living even in fields and marshes in cultivated areas. In midwinter I have taken them from *Microtus* runways in frozen marshes.

Family ZAPODIDAE, Jumping Mice and Allies

Zapus hudsonius hudsonius (Zimmermann)

Little Jumping Mouse

Dipus hudsonius Zimmermann, Geogr. Gesch., 2:358. 1780. Type from Hudson Bay.

Synonyms.—Jaculus hudsonius, Baird, 1857:430; *Meriones acadicus* Dawson, 1856:2.

Distribution.—In Nova Scotia, in suitable habitat throughout the Province.

Remarks.—This species is found most abundantly in grassy meadows and shrub-covered fields. Occasionally, in late summer, I have found family groups of seven or eight individuals together in overgrown weed patches in fruit orchards. Also, on several occasions I have caught this mouse in shallow ditches in open pastures and hay fields. No cover was present in these habitats. Rand (1933:49) recorded these mice from open barren lands and also from situations grown up with conifers. Specimens of *Zapus* taken about the middle of October were extremely fat and therefore were judged to be almost ready to hibernate. Sheldon (1934:290) has given a good account of the habits of this animal in Nova Scotia.

Records of Occurrence.—Specimen examined, 1, from Wolfville, Kings County. Additional records: (Preble, 1899:17): *Antigonish County:* James River, 2; *Halifax County:* Halifax, 6; *Digby County:* Digby, 4. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.) *Kings County:* Wolfville, 1; *Annapolis County:* South Milford, 1; Trout Lake, 1. (E. C. Cross, in *Litt.*, Royal Ont. Mus. Zool.) *Inverness County:* Big Intervale, Margaree River, 2.

Napaeozapus insignis insignis (Miller)

Woodland Jumping Mouse

Zapus insignis Miller, Am. Nat., 25:742. August, 1891. Type from Restigouche River, New Brunswick.

Synonyms.—Meriones labradorius, Dawson, 1856:2; *Jaculus hudsonius*, Baird, 1857:430.

Distribution.—In Nova Scotia, occurring throughout the Province.

Remarks.—The woodland jumping mouse occurs typically in deciduous forests in the vicinity of lakes and streams. Sheldon (1936:213) records this species as being most abundant in sphagnum swamps, although found also in dry hardwood forests. The same author (1934:290) gives much information on the habits of this mouse at Lake Kedgemakooge. Rand (1933:49) found this mouse only in coniferous woods.

Records of Occurrence.—(Preble, 1899:35): *Antigonish County:* James River, 4; *Halifax County:* Halifax, 3. (G. G. Goodwin, in *Litt.*, Am. Mus. Nat. Hist.) *Annapolis County*, 2. (E. T. Hooper, in *Litt.*, Mus. Zool., Univ. Mich.) *Annapolis* or *Queens County:* Lake Kedgemakooge, 15. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.) *Victoria County:* Cape North, 1.

Family ERETHIZONTIDAE, American Porcupines

Erethizon dorsatum dorsatum (Linnaeus)

Porcupine

[*Hystrix*] *dorsata* Linnaeus, Syst. Nat., ed. 10, 1:57. 1758. Type from eastern Canada.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—Although not a common mammal, it is far from scarce. Hemlock and pine forests are typical habitats. It occurs also in deciduous forests of second-growth birch and poplar as well as in the coniferous growths in muskeg and barren land territory.

Records of Occurrence.—(Sight records by present writer): *Pictou County:* Egerton, 1; *Hants County:* Mount Uniacke, 1; West Gore, 2; *Kings County:* Wolfville, 3; Black River Lake, 1; *Annapolis County:* Albany, 2. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.) *Guysborough County:* East Roman Valley, 6.

Order LAGOMORPHA, Rabbits, Hares, and Pikas
Family LEPORIDAE, Hares and Rabbits
Lepus americanus struthopus Bangs
Varying Hare

Lepus americanus struthopus Bangs, Proc. Biol. Soc. Washington, 12:81. March 24, 1898. Type from Digby, Digby County, Nova Scotia.

Distribution.—In Nova Scotia, throughout the Province.

Remarks.—This species is usually a common inhabitant of all the second growth and bush country in the Province. In heavy growths of hardwoods and on many of the barren ridges throughout the interior of Nova Scotia, it is, nevertheless, of unusual occurrence. Alder swamps and young mixed growth are favored territories at all seasons.

In 1927 and 1928, these hares were generally considered to be few in number. In 1931 and 1932 they were plentiful all over the Province. This height of abundance was maintained until the summer of 1932, when the numbers were greatly diminished. The decrease continued until 1936 and since then, up to the present (1938), the numbers have been slowly increasing.

Records of Occurrence.—Specimens examined, 7, all from Gaspereaux Mountain, Kings County. Additional records: (Nelson, 1909:92): *Cape Breton County:* Shenacadie, 2; *Antigonish County:* James River, 1; *Kings County:* 5; *Digby County:* Digby, 13. (R. M. Anderson, in *Litt.*, Nat. Mus. Can.) *Victoria County:* Cape North, 1.

Order ARTIODACTYLA, Even-toed, Hoofed Mammals
Family CERVIDAE, Caribou, Deer, Elk, and Moose
Odocoileus virginianus borealis Miller
White-tailed Deer

Odocoileus americanus borealis Miller, Bull. N. Y. State Mus., 8:83. November 21, 1900. Type from Bucksport, Hancock County, Maine.

Distribution.—Introduced in Nova Scotia; now occurring in all sections of the Province.

Remarks.—The white-tailed deer was introduced into Nova Scotia in 1896, when fourteen animals were liberated near Digby. About twenty-five years later approximately five thousand of both sexes were killed annually in the autumn hunting season. It occurs in almost all parts of the Province and appears to be most plentiful in mixed second growth in proximity to open farmland. This species is steadily increasing in many sections and it is so plentiful, in certain localities, as to constitute a nuisance at times.

That white-tailed deer inhabited Nova Scotia at some time prior to their

introduction in 1896 was shown by Wintemberg's (1919:65) identification of their bones among materials unearthed from Indian shell mounds at two separate localities (see also Grinnell, 1925:136). Evidently these bones date from a time earlier than the 17th century because the French explorers then and later failed to mention any deer in parts of Nova Scotia that they explored and settled. I have found no other mention of the species in the Province before its introduction from New Brunswick in 1896.

Alces americana americana (Clinton)
Moose

Cervus americanus [Clinton], Letters on Nat. Hist. and Int. Resources of New York, p. 193. 1822. Type from "Country north of Whitestown," [probably in the western Adirondack area], New York.

Distribution.—In Nova Scotia, now only on the mainland of the Province.

Remarks.—Moose prefer the bogs and swamps of the interior and can usually be found in areas where sedge swamps and sphagnum bogs occur. Moose were extirpated on Cape Breton Island many years ago and the attempt, in 1928, to restock the island with animals from the mainland has not been successful. On the mainland their numbers are much reduced compared with that in years past. Hunting them is now prohibited in any season.

Records of Occurrence.—Specimens examined, 9, as follows: *Cumberland County:* Wentworth, 1. *Colchester County:* Greenfield, 1; New Annan, 1; Camden, 1; North River, 3. *Antigonish County:* Antigonish, 1. *Annapolis County*, 1.

Rangifer caribou caribou (Gmelin)
Caribou

[*Cervus tarandus*] *caribou* Gmelin, Syst. Nat., 1:177. 1788. Type from eastern Canada.

Distribution.—In Nova Scotia, now extinct; formerly in suitable habitat throughout the Province.

Remarks.—The caribou once was not uncommon. It frequented the muskegs and barren lands. On the mainland it occurred until about 1900. On Cape Breton Island it is thought to have been extirpated in 1912.

In recent years negotiations have been undertaken with the government of Newfoundland to effect the transfer from there of several *Rangifer terranovae* to Cape Breton Island.

Record of Occurrence.—(R. M. Anderson, in *Litt.*, Nat. Mus. Can.): *Cape Breton County:* North Sydney, 1.

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The Biology of Dianthera americana L.

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The so-called water-willow, *Dianthera americana* L., is an emergent aquatic herb of wide distribution in Eastern North America. It is of some concern throughout the southeastern states because dense stands of this species constitute a favorable breeding place for malarial mosquitoes. It is of much interest biologically becouse of several peculiar morphological and ecological features.

Gray's Manual of Botany states that it is to be found "in water, Que. to Wisc., and Vt., s. to Ga. and Tex. July-Sept." Small's Manual of the Southeastern Flora states that it occurs on "beds, shores, and banks of streams, various provinces, Ga. to Tex., Mich., and Que.-Spr.-Sum." It is to be noted that it occurs throughout most of Eastern United States east of the Mississippi River. It is found abundantly throughout the reservoirs of the Tennessee Valley Authority, but is uncommon in the upper part of the Valley.

Habitat.—As has been stated by Small (1933) it occurs on "beds, shores, and banks of streams." It thrives best in streams of considerable flow and is never found in stagnant ponds. *Dianthera* is, however, well established in Lake Wilson, a reservoir of the Tennessee Valley Authority (Fig. 1). This so-called lake is a section of the Tennessee River, the water level of which was elevated by the completion of Wilson Dam in 1925. The species is present also in the "river lakes" of the Alabama Power Company on the Coosa and Tallapoosa Rivers. Although it occurs in these reservoirs, it has never been observed in natural ponds or lakes in the watershed of the Tennessee River.

Dianthera thrives best in six to eighteen inches of water, but survives in wet soil above normal water levels and in water four feet deep (Fig. 1). It occurs on gravelly, sandy, or muddy substrata and is found occasionally on drift and logs. It thrives somewhat better on coarse substrata and apparently is uninjured by deposition of fine gravel and sand. The species occurs in beds of streams, on relatively steep banks as well as on very gradually sloping shorelines. It withstands considerable wave action, but does not survive on exposed headlands where erosion is severe.

Morphology.—*Dianthera* is a perennial herb with fibrous, mostly adventitious roots, prostrate and erect stems, opposite, entire leaves and purplish flowers in axillary, peduncled spikes. When the seed germinates a single primary root is produced, but many adventitious roots are formed shortly and together with the roots from the prostrate stems, constitute the root system of the mature plant (Fig. 2). On well established plants roots occur at each node of the stolons, and on the lower four to eight nodes of the erect stem. The roots are relatively short, devoid of root hairs, and green where exposed to

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sunlight. In cross-section a band of collenchyma, furnished with chloroplasts on the water roots, borders the epidermis. The extensive parenchyma contains abundant air spaces which aggregate about one quarter of the total parenchyma volume. The small central cylinder includes a very thin layer of phloem, a mass of xylem with few vessels but abundant, thick-walled fibers and in the center a mass of very thin-walled parenchyma (Fig. 3).

The stolons are not significantly different from the erect stems except that roots are produced at each node. They creep over the substratum for a distance of several feet and are attached thereto by adventitious roots (Fig. 2). Except where covered with sediment, the stolons and the attached leaves are green. The stolons are not angular but their anatomy is similar to that of the stems. In three representative, dense stands of *Dianthera*, there were 2.3 stolons per plant and nearly 21 lineal feet of stolons per square foot of substratum. This is equivalent to more than 173 miles of stolons per acre. The average maximum length of stolons on August 23, 1937, was 52 inches and it is probable that considerable growth took place after that date. Whenever the upright stems are cut off or poisoned, young shoots are produced at the stolon nodes and the tips of the stolons may become erect shoots. If pieces of stolons or erect stems are detached from the parent plant by mechanical or herbicidal operations, they may float on the water for many days, finally to be deposited on the shoreline, usually among drift. Here they produce offshoots in abundance. Thousands of young *Dianthera* plants, attached to stolon or stem fragments were observed on a line of drift on Lake Wilson on May 30, 1938. They average nearly one per square foot of drift which would be equivalent to about 2 plants per lineal foot of shoreline. The above facts

Fig. 1. Dianthera occurs on rocky to muddy substrata and migrates by stolons into water as much as four feet deep.

amply justify the conclusion reached early in our study that vegetative reproduction is the major means of distribution in this species.

In well established stands of Dianthera, the average number of erect stems is 15 (10 to 22) per square foot. These erect stems vary from less than a foot high in wet soil to nearly five feet tall in the deepest water. In deep water (2 to 4 feet) the lower four to eight nods produce adventitious water roots but no leaves. Just above this point one to five nodes lack both, but still higher, even in water, each node produces two lanceolate, entire leaves. The stem varies in diameter from as much as 0.8 inch near the base (in deep water) to less than 0.1 inch near the tip. It is hexagonal, relatively rigid, with well-developed fibro-vascular and aerenchymous systems. There are six peripheral fibro-vascular bundles and one central strand. These are readily seen in the skeletonized specimens which abound throughout areas where *Dianthera* and *Achyranthes* are in direct competition. In cross-section the epidermis is bordered by alternate masses of collenchyma and chlorenchyma. One fibro-vascular bundle occurs in each angle of the hexagonal stem and consists of a

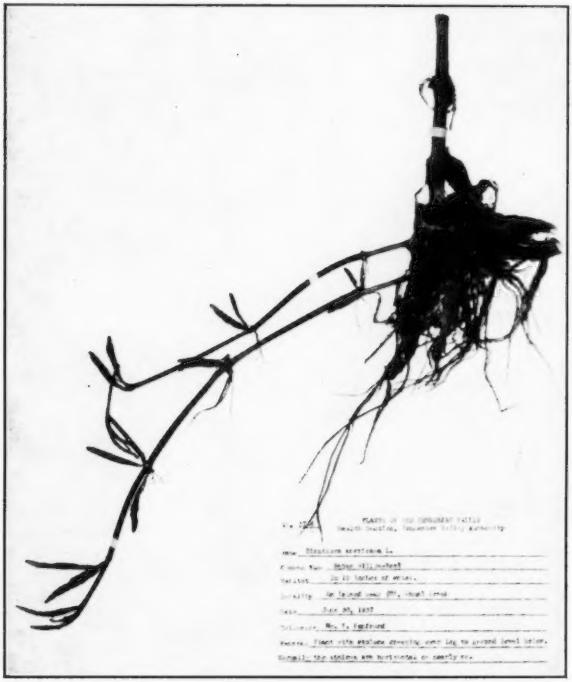
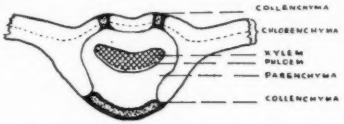


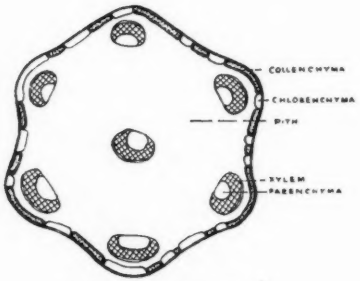
Fig. 2. The extension of colonies of Dianthera is accomplished primarily by leafy stolons.

very thin layer of phloem, a crescentic mass of xylem and a smaller, ellipsoidal patch of parenchyma (Fig. 3). The center of the pith is usually occupied by 1 (often 2 to 4) bundles of similar character, an anomalous and unusual anatomical feature. The pith and cortex are highly aerenchymous. In internodes above the water surface, the air space is 25 to 50 per cent of the total volume of the aerenchyma, whereas it is much higher (50 to 75 per cent) in portions of stems below the water surface. Furthermore, the relative increase in air space is progressive from the tip of the stem downward, indicating the survival value of this anatomical feature.

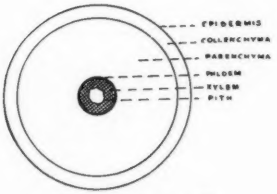
The leaves are sessile, lanceolate, glabrous and entire-margined. They are produced on stolons, as well as on the erect stems, except in water over two



Cross Section Dianthera Leaf, ×40



Dianthera Stem, ×20



Dianthera Root, ×40

Fig. 3. Distinctive anatomical characters include collenchyma in the roots, a central bundle in the stems and two bands of collenchyma on the upper side of the leaves.

feet deep. When covered with sediment the stolons bcome blanched and their leaves turn brown and die. In cross-section the midvein of the leaf is very interesting. The upper epidermis is bordered by chlorenchyma except for patches (usually two) of very thick-walled collenchyma cells (Fig. 3). A large mass of parenchyma, which occupies the main body of the midvein, surrounds the lens-shaped vascular bundle. A colorless fringe of collenchyma borders the lower epidermis. The flanks of the midveins are occupied by chlorenchyma which is continuous with that of the blade proper. The mesophyll consists of two layers of palisade cells and six to ten rows of spongy chlorenchyma. Although the plant grows in water the leaf is quite compact and shows none of the usually accepted hydric modifications.

Flowers.—Although Gray (1908) states that *Dianthera* blooms from July to September, we have found it to bloom as early as May 1, and in full anthesis by June 1. Flowering is practically complete by July 15 except in deep water. However, a second desultory flowering season occurred in late August in the summer of 1937. The axillary peduncled spikes produce delicate flowers which are white or pale lavender, spotted with purple. The flower is peculiar in that each anther is split into two sacs which are separated and somewhat unequal. Each filament, therefore, appears to produce two anthers, thus the name—*Dianthera.*

Fruits.—Fruits are ripened about three weeks after the flower opens. It is a two-carpelled, obovate capsule, shaped like a violin. Each chamber produces two seeds, which are forcibly ejected by a median splitting of the capsule. Although fruits are rarely found floating under natural conditions the floatability was tested experimentally. Green fruits floated for several days, only 27 out of 50 having sunk to the bottom at the end of 12 days. It was quite otherwise with ripe fruits. All of the 50 ripe fruits had submerged completely in seven days.

Seeds.—Each seed is a heart shaped, wafer-like, slightly biconvex structure with a notch near the point of attachment. In an experiment designed to test their floatability, 42 out of 50 seeds had sunk to the bottom in a period of 2 days. Of these, 27 remained on the bottom as seeds, 15 had germinated but remained on the bottom, and 8 had sprouted and risen to the surface. By the end of the twelfth day all the seeds had submerged but 35 of them had germinated and had risen to the surface. In all cases the cotyledons and roots turned green and the seedlings continued to grow until the end of the experiment (12 days).

In the experiment designed to test the floatability of ripe fruits, none of the seeds in the sunken fruits germinated. Twenty-five plump seeds were extracted from these fruits and placed in lake water for a period of six days. At the end of this time 19 out of the 25 seeds had germinated. The average length of the roots was only 4.4 mm. as against 50 mm. in the case of the free seeds. It would be interesting to know why seeds contained in the capsule fail to germinate therein and why they grow so slowly after removal from the capsules.

Dissemination by seeds.—The seeds are ejected forcibly from the capsules to a distance of one to four feet from the parent plant. The sound of split-

ting capsules can be heard for some distance on quiet and dry summer days. When ejected the seeds float on the water surface from one to several hours, usually to be washed on the shore where they germinate immediately. By June 15, many young seedlings may be found on the shoreline. Many observations indicate that most seedlings are found just above the maximum water level of the previous week. On July 1 near a dense stand of parent *Dianthera* the seedlings average about 10 per square foot in the zone of deposition, although as many as 200 per square foot were observed. It is probable that the average in suitable areas for the lake as a whole would be much less than one per square foot since seedlings were not observed very far from parent stands. By August 16, all seedlings possessed two or more pairs of leaves and some possessed as many as eight pairs of leaves and three stolons. By May 27 of the following season some seedlings were observed in flower. From these observations it is readily seen that seeds play an important role in the dissemination of *Dianthera*.

Elimination.—The reduction of *Dianthera* to a point where it will not be a mosquito hazard has been one of the aims of the Division of Malaria Studies and Control of the Health and Safety Department of the Tennessee Valley Authority. It was hoped that this might be accomplished by proper fluctuation and recession of water levels but it is believed that the spread of *Dianthera* has been favored by the schedule thus far utilized. It was believed that freezing might control this species but attenuation is as much as can be expected from this source. Another possibility is the introduction of fungus or insect parasites, but this has not been attempted up to the present time.

The one practice that has offered hope is the application of herbicides. Experiments in the summer of 1937 indicated that an assiduous application of a solution containing 3 percent of sodium arsenite and half as much sodium carbonate was effective either on the entire plants or on the stubble after the erect shoots were removed. Also it was found that the plants could be destroyed by scattering a powdered sodium arsenite-sodium carbonate mixture in the water among the plants. Sodium chlorate also has proved to be a fairly effective herbicide. From our present data it is probable that Dianthera can be reduced to an innocuous state if it appears desirable from the standpoint of mosquito control.

Summary

1. *Dianthera americana L.* is an emergent aquatic herb inhabiting flowing streams throughout much of Eastern North America.

2. *Dianthera* is a perennial herb with fibrous, adventitious roots, stolons, opposite, entire leaves, purplish flowers and fiddle-shaped capsules.

3. Unusual characters of the plant include adventitious water roots, a central fibro-vascular strand in the stolons and stems, and wafer-like seeds which are capable of flotation and immediate germination.

4. Since *Dianthera* presents a moderate mosquito-production hazard, methods have been developed by which it may be reduced to an innocuous state.

The Biology of Achyranthes philoxeroides (Mart.) Standley

William T. Penfound*

The alligator grass, *Achyranthes philoxeroides* (Mart.) Standley is an aquatic herb of wide distribution in South America, Central America and the southern borders of North America. Small's Manual of the Southeastern Flora lists it as growing in "low waste places, ponds, ditches, bayous, and slow streams, Coastal Plain, Fla. to La. and N.C." He adds that "in southern Louisiana this plant is as much of a pest as water hyacinth, often filling up ditches and bayous with a floating mass of growth, usually choking out other plants." This species was first noted in 1935 in Lake Wilson, one of the chain of lakes of the Tennessee Valley Authority. It is now well established in this reservoir and gives promise of becoming a major problem in the breeding of anopheline mosquitoes. Patches of alligator grass were discovered in the Elk River Basin of the Wheeler Reservoir in 1938 and ecesis of this species is expected in the Pickwick and Guntersville Reservoirs unless extreme vigilance is maintained. How it migrated here is unknown, although it is quite possible that it was introduced by shipping by way of the Mississippi and Ohio Rivers.

Growth.—The alligator grass thrives best in relatively flat areas which are protected from wave erosion, especially where it creeps over floating driftwood which has lodged in the upper ends of bights and hollows. In general it becomes established in wet soil near maximum pool level and extends downwards and out over the water by means of prostrate stems. (Fig. 1) In the growing season of 1938, new shoots appeared by March 17 and had attained a length of approximately 15 inches by May 1. This had increased to 25 inches by May 16, at which time it had started to produce flowers. By June 9, the average length of the shoots was 57 inches and the height of anthesis had been reached. By September 1 some of the shoots had attained a length of over 200 inches, and the bands attained a maximum observed width of 15 feet.

This species produces both horizontal, floating stems and vertical shoots which bear the inflorescences. Roots and often new shoots arise at each node on the prostrate stems. When in water the roots never penetrate the soil even when in contact. When an area is dewatered, however, the plant strikes roots and new centers of migration are produced. New shoots are borne both by the larger roots and by the stolons, even where buried by considerable sediment. New plants are produced from stolon fragments as small as a single node which are detached from the parent plant. This occurs readily as one

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walks in patches of this species along relatively steep banks. These floating fragments grow continuously as they float about in the water and take root when deposited along the shoreline. From these facts it is evident that vegetative propagation is of major importance in the dissemination of this species.

The vegetative body.—On an average there are four root masses per square foot of area in favorable situations. The plant possesses relatively large roots (4 to 8 mm.) which occur at the base of the plant proper. The primary xylem is triarch, the secondary xylem being compact and constituting about two-thirds the diameter of the root (Fig. 2). The cortex contains no aerenchyma. The cork is relatively thin and only slightly colored. New plants are produced from these roots, but the method of production has not been observed.

At the junction of the stem with the root, the stem is very small and without aerenchyma. The bundles vary from 8 to 12 in number and are relatively small in cross-section, presumably due to the short distances of

Fig. 1. The alligator grass is well established on Lake Wilson but is readily destroyed by sodium arsenite.

transport because of adventitious roots at each node (Fig. 2). The cortex at this point is not aerenchymous, but the hollow pith affords sufficient buoyancy to float the prostrate stems. The size of the internodes increase gradually up to a point where the erecting stem intersects the water surface. At this point it is about three times the diameter of the stem where it joins the root. The tissue itself is only slightly greater in diameter than that of the lower stem. This slight increase is due to the aerenchymous nature of the cortex. But the major cause of the diameter increase is due to the much greater size of the internal cavity.

The succulent leaves are oblanceolate to spatulate in shape. In comparison with *Dianthera* they contain very little mechanical tissue. In the midvein the upper epidermis is underlaid by a relatively deep patch of beautifully developed collenchyma (Fig. 2). The three fibro-vascular bundles, however, are without evident supporting tissue and are disposed in a large mass of parenchyma. This is underlaid by a thin band of poorly developed collenchyma. Although the midvein is quite distinctive in its anatomy, the mesophyll is very similar to that of the typical mesophytic leaf.

The flower and fruit.—The flowers are perfect and disposed in head-like spikes. The spikes are often called straw-flowers because of chaff-like, persistent white sepals. These petaloid sepals surround a peculiar stamen tube which bears stamens and staminodia alternately on its upper rim. A top-shaped pistil, with a short sytle, completes the flower. The pistil never produces fruit, however, but, together with the rest of the flower, falls off some time before maturity. Neither mature fruits, seeds, or seedlings have ever been found in the Tennessee Valley, although ovaries with immature seeds have been collected many times. It is obvious, therefore, that the rapid spread of this species has been accomplished entirely by vegetative means.

Achyranthes as a competitor.—The alligator grass, *Achyranthes philoxeroides,* and the water-willow, *Dianthera americana,* are the predominant aquatic plants in Lake Wilson and the important species in relation to the breeding of anopheline mosquitoes. It was observed early in the growing period of 1937 that the alligator grass grew much faster than its competitor. Examination of mixed stands indicated also that it overtopped water-willow plants and often prevented them from flowering. Furthermore, many skeletonized shoots of the water-willow were found in mixed stands of the species. Observations on the extension of borders indicated also that the alligator-grass could invade territory occupied by the water-willow.

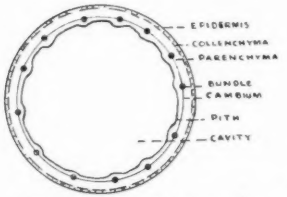
Since *Achyranthes* and *Dianthera* start growth simultaneously in the spring, it was decided to compare the rate of growth in the two species. Representative pure stands of each species were selected in a bight near Wilson Dam and ten typical shoots were measured. The average length of the stems (main stems and branches) was 101 inches for the alligator grass as against 39.8 inches for the water-willow. Since there are more shoots from a root crown of the alligator grass than from one of the competing species it is evident that the diversity in total lineal growth is still greater than that for the average growth of the shoots.

The more rapid growth in *Achyranthes* is directly related to the fact that the dry weight per unit length of stem is much less (0.02 grams per centimeter) than in *Dianthera* (0.04 grams per centimeter). The percent of dry matter in the leaves is also much less (10.6%) than in *Dianthera* (18.1%). The conclusion is reached that the efficiency of *Achyranthes* as a competitor is due largely to its rapid growth and that this growth rate is due to the fact that this species is a trailing plant with little necessity for producing mechanical tissue.

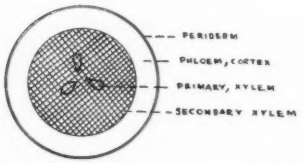
Elimination.—Experiments during the growing season of 1938 were conducted to determine the feasibility of eliminating this species from the reservoirs of the Tennessee Valley Authority. Mechanical removal was attempted by the resident engineer on Lake Wilson, but the results were disappointing. It was believed that freezing might control this species if the lake level were lowered during the winter season, but neither the root crowns nor the stolons below the water line were affected. A slight attenuation, therefore, is all that can be expected from this source.

Experiments have indicated that *Achyranthes* is much more readily killed by herbicides than *Dianthera.* Sodium arsenite, sodium chlorate, potassium chlorate and calcium arsenite in the form of powder have proven effective in the order named. Applied at the rate of 100 pounds per acre all of the cur-

Cross Section of Achyranthes Leaf, ×40



Cross Section of stem of Achyranthes, ×8



Cross Section of Old Root of Achyranthes, ×20

Fig. 2. Distinctive anatomical features of the alligator grass include triarch xylem in the root, and the large, internodal cavities in the succulent stems.

rent growth is killed. Not all of the root crowns are killed, however, as is evidenced by the appearance of new shoots two weeks after the treatment. This is due to the fact that the stolons are often covered with one or more inches of small drift, flotage and sediment. One or, in some cases, two subsequent applications at the point of resprouting were necessary for complete destruction of the species. On the basis of these experiments, routine herbicidal treatment of *Achyranthes* was inaugurated with a view to eliminating this species from Lake Wilson. It was found, however, that the stolons were buried so deeply near the mouths of incoming creeks that it was virtually impossible to reach them with herbicides. Routine herbicidal operations were initiated in July, 1939 on the recently established patches of alligator grass along Elk River in the Wheeler Reservoir and there is every reason to hope that this species will be eliminated from this reservoir by the end of the 1940 growing season.

Summary

1. *Achyranthes philoxeroides* (Mart.) Standley is a floating aquatic herb of restricted distribution in Southeastern United States.

2. This species is a perennial herb, with fibrous, adventitious roots; horizontal and erect stems; opposite, entire leaves, and capitate inflorescences of infertile flowers.

3. Unusual characters of the plant include adventitious water roots, floating stems which produce new shoots upon fragmentation, and the absence of seeds.

4. Since alligator grass presents a favorable environment for the breeding of anopheline mosquitoes, experiments have been conducted to develop methods by which this species may be eliminated from the reservoirs of the Tennessee Valley Authority.

The Biology of Saururus cernuus L.

Thomas F. Hall*

The lizard's tail, *Saururus cernuus* L., is an emergent herb of wide distribution in the United States. Small, in his Manual of the Southeastern Flora, reports that this species is common in the United States, east of the Mississippi River and that it occurs also in Texas. In the Tennessee Valley it has been noted as being one of the most conspicuous herbs in the understory of swamp forests. It also occurs in open ponds of the valley and the marginal terraces, but is not very successful in small ponds as is indicated by the restricted size of the stands. This perennial herb is tolerant to a wide range of temperatures as it thrives not only in the shallow ponded areas but also in cold spring-fed pools.

In the Tennessee Valley old growth stands of tupelo gum or bald cypress-tupelo gum forests contain very little herbaceous vegetation. Lizard's tail has been observed to be one of the most constant species of the herbaceous understories of these swampland communities. In all the primeval stands investigated, this species occupied only those parts of the forest floor in which the average water level varied from 2 to 6 inches above the soil surface. Such situations are usually encountered near the peripheral portions of the swamp forest, but patches of lizard's tail are not uncommon in the swamp proper where favorable conditions exist. Shade plays an important role in keeping this species in check in natural areas as evidenced by the great increase in numbers following clearing operations. In general, when the swamp forests are cleared, suitable environmental conditions for the invasion of aquatics are presented. Lizard's tail *(Saururus cernuus)*, smartweed *(Persicaria hydropiperoides)*, and green arum *(Peltandra virginica)* are the predominant plants of the shallower areas (0-18 in.) whereas the spiny waterleaf *(Nama quadrivalve)* and water purslane *(Isnardia palustris)* are usually the most abundant plants in deeper water (18-30 in.). Because of the notable increase in the amount of lizard's tail in the Wheeler and Pickwick Reservoirs during the summer of 1938, the present study was initiated.

The stand of herbaceous aquatics which was investigated is located in Beaver Dam Creek, one of the many extensive flats of the middle portion of the Wheeler Reservoir (Fig. 1). Beaver Dam Creek is a shallow basin about one-fifth of a mile wide and approximately three miles long. The small stream meanders through the central portion of the basin, and the land rises gently to either side. The site was originally occupied by a well-developed tupelo gum forest, but at the present time, three years after clearing, herbaceous aquatics constitute most of the vegetation found therein. Quadrat studies show that lizard's tail is the predominant species since it presents

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an average cover of 70% accompanied by a high frequency percentage (Table 1).

TABLE 1.—A Comparison of the Three Important species of the Shallow Water Areas of Beaver Dam Creek.

Species	% Cover	Cover Value	Frequency %
Saururus cernuus	70	2.7	95
Persicaria hydropiperoides	30	1.1	90
Peltandra virginica	10±	.5	50

The colony of plants delineated for study included only one herb, the lizard's tail. Occasional specimens of the climbing hemp vine *(Mikania scandens)* were entwined about the upright stems, branches, and inflorescences of the predominant species. Density studies revealed an average of 18 (max. 20; min. 16) plants pr square foot (Fig. 1). It is believed that such uniformity is an excellent index of a community near equilibrium where competition is severe.

TABLE 2.—Summary of Data for *Saururus cernuus*. The Average Values are Based on Data Obtained from the Examination of 10 to 50 Individuals of this Species.

	Average	Minimum	Maximum
Number of plants per square foot	18	16	20
Height	27 in.	24 in.	29 in.
Diameter of Stem at Soil Level	0.5 in.	0.40 in.	0.75 in.
Number Branches per plant	4	1	6
Number Leaves per branch	7	1	14
Area of one surface of leaf	3.7 sq.in.	1.4 sq.in.	6.4 sq.in.
Leaf area—soil surface ratio	13	..	..
Linear feet of rhizome (sq. ft.)	13	..	..
Number of inflorescences per plant	1	0	3
Number of fruits per inflorescence	272	200	350
Number seeds per square foot	20,000	..	..

The mature plants average 27 inches in height and approximately ½ inch in diameter at soil level (Table 2). In general, the lower half of the upright stems lacks leaves and branches, but displays well-developed adventitious roots (Fig. 2). The upper portion of the stems usually bears 3 or 4 (1 to 6) branches averaging 10 inches in length. The cordate leaves are arranged alternately along the zig-zag axes at approximately 1.5 inch intervals. Data indicate an average of 7 leaves per branch with individual counts ranging from 1 to 16. The results are impressive when expressed in terms of a unit area of soil surface. A synthesis of the data indicates an average of 500 leaves for each square foot of soil surface. The area of single leaves (one surface only) as determined by a planimeter ranged from 1.5 to 6.5 square inches, the average area (based on 20 leaves) being 3.7 square inches. This was found to be approximately 13 times the soil surface occupied by the colony.

Both the normal and adventitious roots are fibrous and attain a length of about two inches (Fig. 2). The young root possesses a triarch xylem and a cortex composed of radially disposed cells with air spaces at the corners only (Fig. 3). The aggregate air space was estimated as being only five per cent of the total cortical volume. Outstanding features of the older root are the

central, concentric vascular cylinders and the well-developed aerenchyma of which 60% of the total volume was estimated as air space (Fig. 3).

Subterranean stems, or rhizomes, are abundant one to three inches below the soil surface. The conical growing tip of the rhizome forces its way horizontally through the soil. Its increase in length is accompanied by the formation of a linear series of internodes each averaging one inch in length behind the growing tip. In time, new uprights and rhizomes may arise from the nodes, which in turn continue the vegetative reproductive process. Since the specific gravity of the rhizomes is less than one, fragments are readily transported by water and when stranded on the shoreline they strike root, ultimately producting new colonies and foci of dispersal. Studies reveal an average of 13 linear feet of underground stem for each square foot of soil surface (Fig. 1).

Fig. 1. The lizard's tail is an emergent aquatic herb which reproduces largely by rhizomes as shown in the center of the photograph.

On this basis a network composed of more than 100 miles of rhizomes obtain on each acre of uninterrupted stands. The efficiency of lizard's tail as a competitor is indicated by the fact that numerous dead stems of *Persicaria hydropiperoides* were observed in dense stands of lizard's tail where colonies of the two species were in contact. In the rhizome approximately 50% of the aerenchyma is air space. Excepting for this latter fact and the great abundance of starch granules the rhizome is quite similar in cross section to the aerial stem (Fig. 3).

The aerial stems are largest at the base and gradually taper to the upper extremity (Fig. 2). The stem is well supplied with a ring of closed bundles

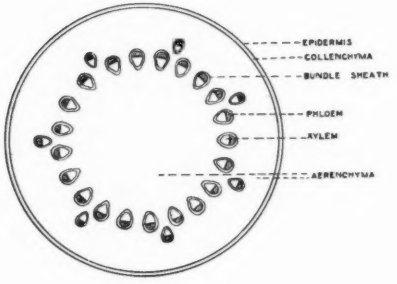
PLANTS OF THE TENNESSEE VALLEY
Health Section, Tennessee Valley Authority
Name, Saururus cernuus L.
Common Name, Lizard's Tail
Habitat, In wet soil and shallow water
Locality, Whiteside, Wheeler Reservoir
Date, June 11, 1938
Collector, Wm. T. Penfound
Remarks, Very common in sluggish streams and ponds, and in ponded areas of reservoirs. A mosquito hazard.

Fig. 2. The mature lizard's tail possesses adventitious roots but no leaves under the water surface.

as well as extrafascicular bundles immediately exterior to the fibrovascular ring (Fig. 3). The number of bundles ranged from 20 to 45 in mature plants. The aerenchymatous tissue is well-developed and constitutes over two-thirds of all tissues in the stem. The volume of air space was estimated at constituting more than 75% of total space occupied by the aerenchyma. Occasional granules of starch are scattered throughout the cells of the aerenchyma. Surrounding the outer layer of the spongy tissue is a narrow band of collenchyma, two to three cell layers thick, with scattered chloroplasts. These bodies are most abundant in the immediately adjacent aerenchyma and gradually decrease in number centripetally (Fig. 3).

The leaves of lizard's tail are heart-shaped and emit a characteristic

Young Root ×80 Old Root ×80



Stem ×15

Petiole ×25 Midrib ×60

Fig. 3. Interesting features of the anatomy of lizard's tail include triarch xylem in the root and extrafascicular closed bundles in the rhizomes and stems.

aromatic odor when crushed (Fig. 2). The older leaves are typically glabrous whereas younger leaves are quite pubescent on both the upper and lower surfaces. A well-developed band of chlorenchyma is revealed by transverse sections and modifications from the typical leaf type are lacking (Fig. 3). The leaves are attached to the zig-zag axes by means of clasping petioles. Features of the petiole are the narrow peripheral band of chlorenchyma and five fibro-vascular bundles arranged in an open U in the parenchyma (Fig. 3).

The light intensity below the dense herbaceous canopy was measured at noon in full sunlight during July (Fig. 1) with a Weston Foot Candle Meter. The lowest reading obtained was 50 foot candles, whereas many readings exceeded the highest intensity measurable by the instrument (600). A value of 150 foot candles was observed as being the reading obtained most frequently in the colony and is equivalent to average values obtained in the shade of a well-developed stand of the tupelo gum forest. The relatively large areas of the leaves, their large numbers, the high sociability and branching habit of individuals of lizard's tail are all conducive to the production of a dense cover.

Inflorescence.—In the Tennessee Valley the first flower buds of lizard's tail open in late May. The height of anthesis is reached by July 1, and three weeks later the plants are heavily laden with fruit. The fruits are retained until September, at which time dissemination occurs. The young inflorescence is a white scorpioid spike which becomes erect as the flowers mature (Fig. 2). The fragrant flowers are showy even though they lack a perianth. A flower consists of six stamens and four distinct carpels which form an urn-like gynaecium upon the boat-shaped subtending bract. The showy appearance of the spike is due to the light yellow anthers, the long white clavate filaments, the light green bracts, and the white pilose peduncle. After the flowers mature, the spike changes color to a greenish gray and the stamens are persistent. The peduncle is approximately six inches long and the distal two-thirds is covered with numerous fruiting bodies (200-350). The diameter of the mature raceme averages approximately three-eights of an inch throughout its entire length. A fruit consists of four carpels (occasionally 3) each one of which produces a solitary seed. Although this does not seem to indicate prolific seed production, approximately twenty thousand seeds per square foot are produced annually. This amounts to nearly nine hundred million seeds per acre per year.

An experiment was designed for the purpose of testing the floatability of the fruits and to determine whether the seeds germinated the same year they are produced. One hundred fruits collectd from ten individuals were placed in a bowl of pond water on July 20, and were observed at half-hour intervals until all were submersed. Additional observations were made during the succeeding two weeks for germination. Approximately one month later the experiment was repeated with more mature fruits. Because of the parallel results obtained, the data of the two experiments were combined and averaged. All fruits floated when placed in the bowl of pond water and by the end of the first half hour five per cent had sunk to the bottom. During the next two and one-half hours ninety per cent of the fruit had become submerged. The remaining five per cent did not sink until an additional hour had elapsed.

Seeds were removed from ripe fruits in August and placed in water. All seeds immediately sunk and remained on the bottom throughout the experiment. In all cases none of the seeds germinated. This seems to indicate that if seedlings occur in nature a period of dormancy is required as is necessary for the seeds of many aquatic plants. In view of the fact that seedlings have never been observed in the field, it is probable that germination rarely occurs in the Tennessee Valley.

Control.—Lizard's tail, a perennial herb, presents one of the most challenging problems in the control of plants conducive to the production of malarial mosquitoes. It covers extensive areas and produces such a dense canopy that larvicidal operations for anopheline control are greatly impeded. In addition, the vegetative propagation is astoundingly rapid. This is accompanied both by the production of erect, leafy stems from the rhizomes and also by the upturning of the tips of the stout, white rhizomes which are an inch or more below the soil surface. Each plant possesses two to four of these underground stems which give rise to new individuals near the periphery of the parent colony.

Cutting.—A square meter plot of lizard's tail was cut approximately three inches above soil level during the first week of August, 1938. At the time cutting occurred, the plants were standing in water twelve inches deep. However, three days later the soil surface was exposed following a "drawdown," and the plot was not inundated during the remainder of the experiment. Observations were made at approximately ten day intervals on both the stem fragments and the rhizomes. The detached stem fragments began to decay during the observation period, whereas the stubble produced new shoots in ten days. During the same period of time the tips of the rhizomes had turned upward, but none had emerged from the soil. Twenty days after cutting many of the rhizome tips had broken the soil surface and had yielded one or two leaves each. Field counts showed that from two to four new individuals had been produced for each plant cut. Thus, it is seen that cutting actually results in an increase in the density of the stands.

A similar experiment was performed in July, 1939, on a plot of lizard's tail which was not subjected to dewatering. In general, the results were parallel, but the *floating* fragments of the stems produced adventitious roots one inch long two weeks after cutting. Fragments with water roots, when stranded along the shore, became rooted and gave rise to new colonies.

Inundation.— Lizard's tail withstands temporary indundation admirably. At Beaver Dam Creek water covered the plants completely for a period of two weeks, but, when the colony was dewatered, the plants were heavily covered with a black layer of decomposing algae and other decaying organic matter which often resulted in defoliation. Approximately ten days after the "drawdown" one or two new leaves appeared at the tip of each defoliated branch. In natural areas, this species has been observed to survive heroic inundation of more than a month's duration. In fact, temporary inundation seems to be one of the main requisites for its establishment and survival.

Herbicides.—Experiments were conducted to test the feasibility of con-

trolling this species by means of herbicides. Hydrocarbons applied to the entire plants and stubble at prohibitive rates failed to reduce the density of the stands. To date, sodium arsenite has been the only herbicide to yield encouraging results. Applications on experimental plots were made at rates of 3.5, 10, and 100 pounds per acre. On the plants which received the smallest dosage eighty per cent of the leaves were dead two weeks after treatment, but the remainder of the plant showed little effect of the poison. On the 10 pounds per acre plot, all of the leaves were killed as well as the uprights down to the water-line, but abundant new plants were produced from the rhizomes and partially destroyed upright stems. The individuals which received the largest dosage (100 lbs. per acre) were completely blackened two weeks after treatment and, ultimately the entire uprights and rhizomes succumbed. One year after the experiment had been initiated, no living plants of lizard's tail were observed, but numerous seedlings of various species had invaded the area indicating that sterilization of the blue-gray soil had not been obtained. In future experiments, repeated applications of sodium arsenite at rates varying from 3.5 pounds to 10 pounds per acre will be utilized. It is hoped that sufficient attenuation of the species may be obtained by repeated treatments in low dosages to obtain efficient larvicidal control of malarial mosquitoes.

Summary

1. The lizard's tail, *Saururus cernuus* L., is an emergent, aquatic species of wide distribution in Eastern United States.

2. This species is a perennial herb with fibrous, adventitious roots, upright stems, well-developed rhizomes, cordate leaves atranged alternately along the zig-zag stems, and apparently non-viable seeds.

3. The rapid increase in the size of the colonies is due to its rhizomatous habit. Dissemination is accomplished mainly by fragmentation of rhizomes and the erect stems.

4. Dense stands of the lizard's tail provide environmental conditions conducive to the production of anopheline larvae and the well-developed leafy horizon greatly impedes the application of larvicides.

5. Attenuation of this species may be accomplished readily by the application of sodium arsenite.

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BOOK REVIEWS

FORAMINIFERA, THEIR CLASSIFICATION AND ECONOMIC USE, with an Illustrated Key to the Genera. By Joseph A. Cushman, Harvard University Press, 1940, 3rd ed.; 535 pp., 79 pls., text figs. $6.00.

BY HELEN JEANNE PLUMMER

(In collaboration with R. Wright Barker and M. L. Thompson)

This new edition of the indispensible guide for the student of Foraminifera comprises a single volume of 535 pages, 31 plates of line and stipple drawings, 48 full-tone plates with black background, which have proved so satisfactory, and several scattered figures and charts. The binding is distinctive and durable, the paper excellent, and the typography, spacing, and indentation are essentially of the same character as those of the previous edition. Those who have been working with the second edition will feel very much at home with the new volume, which is practically a duplication of the former edition with the addition of descriptions of some of the recently erected genera accompanied by illustrations on plates 41 to 48. The first 394 pages correspond to Special Publication No. 4 (Cushman Lab. Foram. Res.) and carry the same illustrations, except that two charts have been omitted. Pages 395 to 522, accompanied by plates 1 to 48, comprise the very usable key originally issued as Special Publication No. 5. The index falls at the end. Since page reference throughout the key and on plates descriptions have been so generously and conveniently offered, it is difficult to imagine any disappointment in the present form of a single volume.

Chapters 1 to 10 have been reprinted with only minor alterations and additions. The up-to-date student will be disappointed not to find in Chapter 1 a review of the epoch-making investigations by Earl Meyers on life histories of several forms of the Foraminifera. In Chapter 2 the author presents further evidence of the chitinous character of the Cambrian *Spirillina groomi* Chapman, as a result of study of typical thin sections by petrographers. In Chapter 3 on collecting, a new paragraph takes into account some recent work of coring the ocean bottom. Chapter 4, on methods of study, points out the availability of a new type of slide with a metal sheath now on the market, and also mentions the author's present use of the Leica camera, which has proved highly satisfactory in producing negatives on fine-emulsion films that permit considerable enlargement. The last paragraph of Chapter 7 on geologic distribution should have been emended to account for the omission of two of the three charts included in the former edition.

Chapter 11, which constitutes the bulk of the volume, comprises the systematic descriptions of the taxonomic units, and the organization of the material is the same as in the previous edition. The family Fusulinidae has been treated by Carl O. Dunbar; the orbitoids by T. Wayland Vaughan and W. Storrs Cole. All the family groups remain the same, except that the orbitoids are now ranged under three family names, two of which are new to the science in this volume: *Discocyclinidae* Vaughan and Cole, n.fam., and *Miogypsinidae* Vaughan and Cole, n. fam. The name of one subfamily has been changed, and one new subfamily is named for the first time here (*Helicolepidinae* Vaughan and Cole, n. subfam.). Newly recognized generic structures are offered under 110 generic names, most of which have been described since the printing of the second edition. The names of 4 generic structures in the previous edition have been found invalid and have been changed, either by the substitution of other old names not generally in use until now or by new names that have recently been assigned. Two generic names have been suppressed and are now found in synonymy. Twelve subgenera are offered under center headings; most of these have been named within the last few years, but two are new in this publication (*Proporocyclina* Vaughan and Cole, n. subgen., and *Athecocyclina* Vaughan and Cole, n. subgen.).

The family groups that present additions and revisions are discussed separately in the following paragraphs.

Family ASTRORHIZIDAE—The genus *Armorella* Heron-Allen and Earland has been removed from the synonymy for *Astrammina* and recognized as a genus in the Saccamminidae.

Family RHIZAMMINIDAE—The range of *Rhizammina* is now extended downward into the Jurassic.

Family SACCAMMINIDAE—*Leptodermella* Rhumbler has been substituted for *Pseudarcella* Spandel, which formerly was used incorrectly. *Armorella* Heron-Allen and Earland has been removed from the synonymy for *Astrammina* in the Astrorhizidae and is now an accepted genus in this family group. Six new structures are recognized: *Pilalla* Rhumbler, *Causia* Rhumbler, *Ceratammina* Ireland, *Amphifenestrella* Rhumbler, *Kerionammina* Moreman, and *Aguayoina* Bermudez (regarded as a probable coral by English paleontologists). *Psammella* Rhumbler has been added to the synonymy for *Psammosphaera*. The range of *Saccammina* is extended down into the Silurian.

Family HYPERAMMINIDAE—The structure, *Saccodendron* Rhumbler, has been added, and the ranges of *Jaculella*, *Saccorhiza*, and *Dendrophrya* have been extended either questionably or definitely.

Family REOPHACIDAE—The only change in this group is in the range of *Haplostiche*, which is no longer regarded as occurring possibly in the Carboniferous.

Family AMMODISCIDAE—In the discussion of the family Dr. Cushman reports further investigation of the Cambrian *Spirillina*-like forms by petrographers, and records that the general agreement is that they were chitinous and can not therefore be either *Spirillina* or *Ammodiscus*. Three new structures have been added to this family group: *Spirillinoides* Rhumbler, *Ammoflintina* Earland, and *Bifurcammina* Ireland. The chart showing the relationships and geologic distribution of the Ammodiscidae has been omtted from this new edition.

Family LITUOLIDAE—The genus *Orbignyna* has been removed from this family and placed in the Valvulinidae (although in the discussion of the family this genus is still featured). Two structures have been added under the generic designations *Recurvoides* Earland and *Alveolophragmium* Stschedrina. The ranges of *Ammomarginulina*, *Frankeina*, and *Cyclammina* have been extended down into the Jurassic, either questionably or definitely.

Family TEXTULARIIDAE—At the end of the discussion of the family is a new paragraph commenting on the peculiar genus *Pseudobolivina* Wiesner, which needs further study; temporarily it is placed in the synonymy for *Textularia*, where it should be recorded in full, *Pseudobolivina* Wiesner, 1931. Five generic structures have been added under the names, *Semitextularia* Miller and Carmer, *Spiroplectella* Earland, *Silicotextulina* Deflandre (no figures have ever been made avaliable, and the genus is in question), *Siphotextularia* Finlay, and *Haeuslerella* Parr (not included in the revised key). *Spandelinoides* Cushman and Waters is still not to be found either as an accepted genus under center heading or in any synonymy. The genus *Ammobaculoides* is still described as calcareous, whereas the tests of the genotype are composed of quartz grains bound by an insoluble cement.

Family VERNEUILINIDAE—In the discussion of the family minor changes have been made to take into account some of the newly recognized genera. Six genera have been added: *Barbourina* Bermudez, *Bermudezina* Cushman, *Pseudoclavulina* Cushman, *Clavulinoides* Cushman, *Pseudogaudryinella* Cushman, and *Rudigaudryina* Cushman and McCulloch. Under *Gaudryina* the subgenera *Gaudryina* s.s., *Siphogaudryina* Cushman, and *Pseudogaudryina* Cushman are duly treated. The descriptions of *Verneuilina*, *Tritaxia*, *Heterostomella*, and *Gaudryina* have been considerably amplified.

Family VALVULINIDAE—The genus *Pseudorbitolina* Douvillé, formerly mentioned in the discussion of the family Orbitolinidae as a possible member of that group, is now

treated as an acceptable genus in this family, and a Cuban form is figured to illustrate the structure (reference to figures under center heading, p. 127, should read: figures 10, 11). *Orbignyna* has been transferred from the family Lituolidae to this family group. *Martinottiella* now falls in synonymy under *Listerella*. Four generic structures have been added to this family under the names *Valvulammina* Cushman, *Matanzia* D. K. Palmer (initials must be employed, since K. van W. Palmer was the first author of this name to describe Foraminifera), *Cubanina* D. K. Palmer, and *Cribrogoësella* Cushman. The ranges of *Clavulina*, *Arenobulimina*, and *Marssonella* have been restricted; those of *Lituonella*, *Coskinolina*, and *Dictyoconus* have been extended; that of *Goësella* has been more definitely stated as Cretaceous to Recent. Descriptions of *Valvulina* and *Ataxophragmium* have been amplified. The chart showing the relationships and geologic distribution of the Valvulinidae has been omitted. Since both Silvestri and Davies have within very recent years recognized *Dictyoconus* in the Texas Lower Cretaceous (*D. walnutensis* (Carsey)), an extension of the range is expected, or some comment should have been made as to why the opinions of these outstanding students can not be accepted. The perforate character of the test of *Gunteria*, as proved by thin sections figured by Davies during the past year, receives no recognition, but should be further considered by students working in this group.

Family FUSULINIDAE[1]—Four subfamilies are recognized: Fusulininae Rhumbler, Schwagerininae Dunbar and Henbest, Verbeekininae Staff and Wedekind, and Neoschwagerininae Dunbar and Condra. Thirty-six genera and two subgenera are regarded as valid. The following genera that did not appear in the family Fusulinidae in the second edition are recognized in this edition: *Nummulostegina* Schubert, *Ozawainella* Thompson, *Leëlla* Dunbar and Skinner, *Boultonia* Lee, *Codonofusiella* Dunbar and Skinner, *Eoschubertella* Thompson, *Yangchienia* Lee, *Pisolina* Lee, *Sphaerulina* Lee, *Nankinella* Lee, *Schwagerina (Rugofusulina)* Rauser-Cernoussova, *Pseudoschwagerina* Dunbar and Skinner (=*Schwagerina*, part, 1933 edition), *Pseudoschwagerina (Zellia)* Kahler and Kahler, *Paraschwagerina* Dunbar and Skinner (=*Schwagerina*, part, 1933 edition), *Nipponitella* Hanzawa, *Gallawainella* Chen (=*Gallowaiina* Chen), *Quasifusulina* Chen, *Eoverbeekina* Lee, *Colania* Lee, and *Lepidolina* Lee. The genus *Neofusulinella* Deprat, 1912, has not been discussed; this is probably an oversight.

Family SILICINIDAE—The subfamily Silicininae is now known as Involutininae. The recently erected genus, *Spirolocammina* Earland, has been added to this group. The range of *Miliammina* has been extended back into the Cretaceous.

Family MILIOLIDAE—Five recently described structures are included in this family group: *Proemassilina* Lacroix, *Pseudomassilina* Lacroix, *Riveroina* Bermudez, *Cribrolinoides* Cushman and LeRoy, and *Pyrgoella* Cushman and E. M. White (initials necessary). The ranges of *Tubinella* and *Flintina* are now reported in Tertiary sediments, as well as in Recent deposits.

Family OPHTHALMIDIIDAE—The subfamily Nodobacularinae is now known as *Nodophthalmidiinae* to correspond to the substitution of the generic name *Nodophthalmidium* Macfadyen for the invalid *Nodobacularia* Rhumbler. Five recently described structures have been added under the names *Nodobacullariella* Cushman and Hanzawa, *Ophthalmina* Rhumbler, *Meandroloculina* Bogdanowicz, *Rhizonubecula* LeCalvez, and *Glomulina* Rhumbler.

Family TROCHAMMINIDAE—The treatment of this family differs in the new edition only in the addition of two structures designated as *Remaneica* Rhumbler and *Ammocibicides* Earland, and in the extension of the ranges of *Ammosphaeroidina* and *Nouria* down into the Tertiary.

Family PLACOPSILINIDAE—The new features comprise the recently described genera *Placopsilinella* Earland and *Adhaerentia* Plummer, and the extension of the range of *Haddonia* down into the Eocene.

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[1] Reviewed by M. L. Thompson, New Mexico School of Mines, Socorro, New Mexico.

Family ORBITOLINIDAE—The genus *Pseudorbitolina* Douvillé, which was formerly mentioned in the discussion of this family as a possible member, has now been removed from this questionable position and placed in the Valvulinidae as a recognized genus, therefore the last paragraph under *Orbitolina* should have been deleted. The present discussion of the family mentions *Orbitolinopsis* A. Silvestri and its genotype species *Orbitolina conulus* Douvillé, but the structure is not treated formally under a center heading in this family group, probably because it is not yet sufficiently understood.

Family LAGENIDAE—The name *Palmula* Lea has been substituted for the structure formerly known as *Flabellina*. Two recently erected frondicularian structures are recognized as *Dyofrondicularia* Asano and *Parafrondicularia Asano*. The recently described new genera *Svenia* Brotzen and *Saracenella* Franke are treated as synonyms of *Dentalina* and *Saracenaria* respectively.

Family POLYMORPHINIDAE—A brief paragraph at the end of the discussion of the family calls attention to the Jurassic genus *Ramulinella* Paalzow, for a better understanding of which more work is needed. The two rather newly recognized genera, *Polymorphinella* Cushman and Hanzawa and *Polymorphinoides* Cushman and Hanzawa have been added.

Family NONIONIDAE—The discussion of the family is changed only in the inclusion of *Notorotalia* and *Astrononion* in their proper relationships. Three genera erected since the last edition have been added: *Astrononion* Cushman and Edwards, *Elphidiella* Cushman, and *Notorotalia* Finlay. The range of *Elphidium* has been restricted to the Tertiary.

Family CAMERINIDAE—Two new generic structures have been added to this family group, *Operculinoides* Hanzawa and *Miscellanea* Pfender, and one subgenus (under *Operculina*), *Sulcoperculina* Thalmann. It is curious that the old treatment of *Nummulostegina* Schubert, 1907, remains the same and as a member of this family, although it is newly treated as a distinct genus in the Fusulinidae. The subgenotype of *Sulcoperculina* belongs to the Upper Cretaceous strata in Cuba, not the Eocene as recorded.

Family PENEROPLIDAE—At the end of the discussion of the family a new paragraph mentions the insufficiently understood genus *Somalina* A. Silvestri, which at present can not be placed in the classification; the suggestion is made that it may belong either amongst the orbitoids or in this family group.

Family ALVEOLINELLIDAE—The discussion of this family now points to its origin in the Cretaceous rather than in the Eocene, consequently the brief fifth paragraph of the earlier edition is now omitted. Two new paragraphs at the end of the discussion of the family call attention to Reichel's detailed studies and to *Neoalveolina* A. Silvestri, which at present is of doubtful validity and is included in the synonymy for *Borelis*. The four recently described Reichel genera, *Ovalveolina*, *Praealveolina*, *Subalveolina*, and *Bullalveolina*, are included in this family group. Under *Borelis* a new paragraph introduces and briefly defines the subgeneric groups recognized by Reichel: *Glomalveolina* Reichel, *Fasciolites* Parkinson, *Eoalveolinella* A. Silvestri. In the range for *Borelis* its *Recent* occurrence is now questioned. The range for *Alveolinella* is now definitely "Miocene to Recent."

Family HETEROHELICIDAE—This group of genera has been enlarged by the addition of *Zeauvigerina* Finlay. The name *Bolivinopsis* Yakovlev has been substituted for *Spiroplectoides* Cushman. The range of *Gümbelina* has been extended upward to include the Oligocene, and that of *Amphimorphina* is extended back into the Eocene.

Family BULIMINIDAE—At the end of the discussion of the family, the poorly understood genus *Buliminopsis* Rzehak is suggested as a possible member of this group. Eight recently described structures are presented under the generic names, *Pseudobulimina* Earland, *Suggrunda* W. Hoffmeister and C. Berry, *Bifarinella* Cushman and Hanzawa, *Geminaricta* Cushman, *Bitubulogenerina* Howe, *Tritubulogenerina* Howe, *Unicosiphonia* Cushman, and *Delosina* Wiesner. The subgenus *Virgulinella* Cushman has been added

to define a special form of *Virgulina*. The range of *Chrysalidinella* has been extended down into the Eocene, that of *Bifarina* has been extended questionably down into the Jurassic, and that of *Dentalinopsis* definitely into the Jurassic.

Family ELLIPSOIDINIDAE—The only new features consist of a recently erected genus *Pinaria* Bermudez and of the questionable extensions of the ranges of two genera, *Ellipsobulimina* and *Ellipsoglandulina*, to include the Cretaceous and Jurassic respectively.

Family ROTALIIDAE—In the discussion of the family mention is made that several specialized genera have been described (no names listed) which illustrate parallelisms in this family group. At the end of this discussion attention is called to *Nuttallides* Finlay, which at present is too uncertain to treat in the classification. Eleven recently described generic structures have been added: *Coscinoconus* Leupold and Bigler, *Conorbina* Brotzen, *Discorbinella* Cushman and Martin, *Earlmyersia* Rhumbler (not included in the key, except by plate figures), *Stensiöina* Brotzen, *Eponidella* Cushman and Hedberg, *Rotalidium* Asano, *Rectoeponides* Cushman and Bermudez, *Coleites* Plummer, *Asanoina* Finlay, and *Sakesaria* Davies and Pinfold. The ranges of *Heronallenia* and *Baggina* have been extended down into the Eocene.

Family CALCARINIDAE—The only new features in this group comprise the addition of the unillustrated *Biplanispira* Umbgrove and the restriction of the range of *Siderolites* to the Upper Cretaceous. Even though Hanzawa's recently introduced family Pellatispiridae, 1937, including *Pellatispira* and *Pellatispirella* may not be wholly acceptable, some reference to this together with Barker's discussion of the problem (1939) would lead the student to significant contributions.

Family CYMBALOPORIDAE—At the end of the discussion of the family a short new paragraph calls attention to the peculiar relationships of the chambers in *Pyropilus* Cushman, which is the only structure added to this family group.

Family CASSIDULINIDAE—In the discussion of the family a short paragraph has been inserted to introduce the peculiar and recently described generic structures, *Cushmanella* D. K. Palmer and Bermudez, *Epistominoides* Plummer, and *Pseudobulimina* Earland (which is supposedly included in this family but is formally treated in the Buliminidae). The first two genera just named constitute the only additions to this family. *Parrella* Finlay is an added synonym for *Pulvinulinella*.

Family CHILOSTOMELLIDAE—The only change is the extension of the range of *Seabrookia* down into the Cretaceous.

Family GLOBIGERINIDAE—At the end of the discussion of this family is a brief paragraph mentioning the recently described peculiar form, *Candorbulina* Jedlitschka, with the suggestion that it may represent the globular end form of *Candeina*. The genus *Candorbulina* constitutes the only addition to the family.

Family HANTKENINIDAE—The subgenus *Sporohantkenina* Bermudez is the only new feature of this family group and is typified by the well-known *Hantkenina brevispina* Cushman.

Family GLOBOROTALIIDAE—*Cribrogloborotalia* Cushman and Bermudez is the only addition to this family. The Recent occurrence of *Globotruncana* is now questioned in the range record, though by general consensus of opinion it is deleted.

Family ANOMALINIDAE—In the discussion of the family a new sentence places *Stichocibicides* Cushman and Bermudez and *Palmerinella* Bermudez into the phylogenetic scheme, and under center headings the two genera are formally presented as additions to the family group. The range of *Anomalina* is questionably extended downward into the Jurassic.

Family PLANORBULINIDAE—The only change involves questionable occurrences of *Acervulina* in the Jurassic and Cretaceous.

Family RUPERTIIDAE—The recently recognized structure, *Neocarpenteria* Cushman and Bermudez, has been added to this group of genera.

Family HOMOTREMIDAE—The ranges of *Homotrema* and *Sporadotrema* have been extended down into the Tertiary.

Families ORBITOIDIDAE, DISCOCYCLINIDAE, MIOGYPSINIDAE[2]—The family *Orbitoididae*, contributed to earlier editions of the manual by T. Wayland Vaughan, consisted of 5 subfamilies and 22 genera and subgenera, constituting an admirable summary of this somewhat confusing group of the so-called "larger foraminifera." The descriptions contained much original information and a concise compilation of data obtained from a large number of publications which proved of great value to both the general worker and the specialist. In the present edition this section has been dealt with by Dr. Vaughan in collaboration with Dr. W. Storrs Cole, and in an attempt to keep up with the ever-increasing output of numerous research workers, it has been very considerably enlarged. Thus we now have three families *(Orbitoididae, Discocyclinidae* and *Miogypsinidae)*, three subfamilies, and thirty-three genera and subgenera.

In the revised descriptions much emphasis has rightly been laid upon the arrangement of the "stoloniferous apertures" or stolons, and the stolon-system has been noted for a large number of the genera largely as a result of researches by the compilers. Little has been added, however, regarding the relationships of the various subfamilies, genera and subgenera, their nepionic structure, or their possible evolution, although considerable work has been done on these lines since 1933. Surprise is occasioned by the apparent disregard of the numerous papers of Tan Sin Hok, in which are summarized his researches on the orbitoids and allied groups since 1932.

Thus, in 1932, W. Scheffen proposed the family *Lepidocyclinidae*, which appears to have been neglected until 1936, when Tan published an emended account (see "Beitrag zur Kenntnis der Lepidocycliniden," Proc. Kon. Akad. Wetensch. Amsterdam, 1936, vol. 39, pp. 990-999, and "Zur Kenntnis der Lepidocycliniden," 1936, Natuurk. Tijdschr., vol. 96, pp. 235-280). Tan based his argument on evidence published the same year by Barker and Grimsdale (Journ. Pal., vol. 10, pp. 231-247) which attempted to show that *Helicolepidina* and certain species of *Lepidocyclina (Polylepidina)* were related to *Amphistegina*, through the new genera *Eulinderina* and *Helicostegina*. Tan divided *Lepidocyclinidae* into two subfamilies: *Lepidocylininae* and *Helicolepidininae*, thus antedating Vaughan and Cole's subfamily *Helicolepidinae* by four years. There remain, however, certain points to be criticized in the arrangement of certain of the genera in Tan's families and subfamilies, and also in the use of *Cyclolepidina, Tryblio-lepidina*, and *Orbitocyclina* (all referred to synonymies in the present account). The validity of *Orbitocyclina* has, however, been defended by Tan in a recent paper not referred to in the new classification (see Tan, 1939, "On *Polylepidina, Orbitocyclina*, and *Lepidorbitoides*," Die Ingenieur in Ned.-Indie," IV, Mijn. en Geol., Jaarg. 6, no. 5, pp. 53-84, pls. 1, 2).

The family *Miogypsinidae* (given as new, Vaughan and Cole, 1940) was likewise proposed by Tan in 1936 (Die Ingenieur in Ned.-Indie, III, Mijn. en Geol., pt. 4, p. 45). Tan arrived at the conclusion that *Miogypsina* and allied forms were related to *Rotalia* and possessed a canal-system, and were therefore to be separated from the *Orbitoididae*, a conclusion reached independently by Barker and Grimsdale while Tan's paper was in the press (see Barker and Grimsdale, Ann. Mag. Nat. Hist., ser. 10, vol. 19, pp. 161-168, Feb., 1937). This conclusion was also reached by F. R. S. Henson in Syria (personal communication) and is supported by large suites of specimens from the subsurface of the Gulf Coast, where *Rotalia* can be separated only with difficulty from young specimens of *Miogypsinoides*. It is regrettable that a recent paper by Prof. S. Hanzawa, containing a revision of the *Miogypsinidae* ("Micropaleontological Studies of Drill Cores from a Deep Well in Kita-Diata-Zima (North Borodino Island)," Jubilee Publ. Prof. H. Yabe's 60th Birthday, pp. 755-802, pls. 39-42) appeared too late to be discussed by Vaughan and Cole, since here the *Miogypsininae* are regarded

2 Reviewed by R. Wright Barker, Shell Oil Co., Houston, Texas.

as a subfamily of *Rotaliidae* Reuss, and *Miogypsinella* and *Miogypsinopsis* are erected as new genera, the subgenus *Conomiogypsinoides* Tan, 1936, being regarded as probably synonymous with *Miogypsinoides*.

One of the most marked changes in the new edition is the raising of *Discocyclinidae* to family rank (partly owing to the probable existence of a canal-system in certain species), with division into two genera and four subgenera, the generic differentiation being based on the position (distal or proximal) of the annular stolons. It is not clear, however, why three groups (one genus and two subgenera) are required for those species possessing distally placed annular stolons. It is stated that *Pseudophragmina* possesses distally placed annular stolons and radial chamber walls which "may be complete, incomplete, absent, or indistinct." The new subgenus *Proporocyclina* possesses distal annular stolons and "chamber walls complete" and a second subgenus *Athecocyclina* is then erected for specimens with distally placed stolons with "radial walls absent or indistinct." It would appear preferable and more in agreement with common usage to restrict the species to one genus and one subgenus thus avoiding further overcrowding of an already somewhat overloaded nomenclature.

The omission of several of the older synonyms may tend to confuse new workers (such as *Exagonocyclina* Checcia-Rispoli, 1909; *Flabelliporus* Dervieux, 1893; *Hymenocyclus* Bronn, 1853; *Lepidosemicyclina* L. Rutten, 1911; and *Orbulites* Lamarck, 1801). A number of genera, many of which may prove to be valid, appear to have escaped the authors' attention. Among those noted are *Asterodiscocyclina* Berry, 1928 (probably an *Aktinocyclina*); *Astrolepidina* Silvestri, 1931 (new name for stellate species of *Lepidocyclina*); *Conomiogypsinoides* Tan, 1936 (subgenus of *Miogypsinoides*); *Helicocyclina* Tan, 1936; *Helicolepidinoides* Tan, 1936; *Helicostegina* Barker and Grimsdale (according to Tan, 1936, a synonym for *Eulinderina* Barker and Grimsdale); and *Orbitoclypeus* Silvestri, 1907.

In the extensive bibliography there are also some rather unexpected omissions, even taking into account the fact that the list is only a selection from a vastly greater number of publications. Thus Silvestri's account of the Oligocene and Miocene foraminifera of Somaliland is included, but his accounts of the Cretaceous (Pal. Ital., vol. 32, 1932, pp. 143-204, pls. 9-16) and the Eocene (Pal. Ital., vol. 32, suppl. 3, 1938, pp. 49-89, pls. 1-10; suppl. 4, 1939, pp. 1-102, pls. 9-22) are lacking. Among works on the *Camerinidae*, although a number are listed, there are no references to such conspicuous contributions as that of Boussac, or those of Rozlozsnik (1926-29), or the short discussion of the "English Bartonian Nummulites" by Dennis Curry (1937).

Among general classifications one might have expected to find a reference to A. Morley Davies' "Tertiary Foraminifera" (in: "Tertiary Faunas," vol. 1, 1935, pp. 1-63, figs. 1-107). O. Protescu's paper, "Contributuini la Studiul Faunei di Foraminifere Tertiare din Romania" (An. Instit. Geol. Romaniei, vol. 9, 1915-1920 (1921), pp. 221-372, 4 pls.), is also conspicuous by its absence. Dealing with larger foraminifera apart from *Fusulinidae* and *Camerina* one misses Gomez Llueca's "Los Numulitidos de Espana," Madrid, 1929, 400 pp., 34 pls. (includes *Discocyclina* and *Lepidocyclina*), Tan Sin Hok's, "On the Genus *Cycloclypeus* Carpenter, Part I," 1932, 194 pp., 24 pls., his "Zur Kenntnis der Lepidocyclinidae," 1936, 45 pp., and his final paper on the *Miogypsinidae*, "Weitere Untersuchungen über die Miogypsiniden II," 1937, 25 pp. and 4 pls., in which references are made to several American species. It is also felt that Barker and Grimsdale's "A Contribution to the Phylogeny of the Orbitoidal Foraminifera with Descriptions of New Forms from the Eocene of Mexico," 1936, 17 pp. and 9 pls., might be given precedence over the scrappy notes on Ecuadorean foraminifera published by Barker in 1932.

Although it must be admitted that the present account appears to be less complete than its predecessors in comparison with results published, it is still an excellent guide to the general worker. The omission of such a high proportion of the later described genera and the failure to discuss various alternative classifications and evolutionary theories, renders it less valuable than it might have been to the specialist, yet it still remains indispensable to any student of the foraminifera.

The following generic names (many being probably valid genera) proposed in recent years, in addition to a large number (over 100) to be found in Galloway's "Manual of the Foraminifera," have received no consideration in this new edition:

Amphitremoida Eisenach, 1937. Palaeont. Zeit., vol. 19, p. 235. Genotype, *A. citroniforma* Eisenach.

Arenosiphon Grubbs, 1939. Jour. Paleont., vol. 13, p. 544. Genotype, *A. gigantea* Grubbs.

Astrolepidina A. Silvestri, 1931. Riv. Ital. Paleont., vol. 37, p. 35. New subgenus for stellate forms of *Lepidocyclina*.

Borelia Sorrentino, 1934. Boll. Soc. nat. Napoli, vol. 46, p. 137. No subgenotype named. New subgenus of *Fasciolites* Parkinson.

Checchiaites Sorrentino, 1934. Boll. Soc. Nat. Napoli, vol. 46, p. 137. New subgenus of *Flosculina* Stache. Subgenotype, *F. daunica* Cheechia-Rispoli, 1912.

Chitinodendron Eisenach, 1937. Palaeont. Zeit., vol. 19, p. 236. Genotype, *C. bacciferum* Eisenach.

Cibicidoides Brotzen, 1936. Sveriges geol. undersökning, ser. C, no. 396, Arsbok 30, no. 3, p. 186. New subgenus of *Cibicides*. Subgenotype, *Truncatulina mundula* H. B. Brady, Parker, and Jones, 1888.

Citharinella Marie, 1938. Bull. Soc. géol. France, ser. 5, vol. 8, p. 100. Genotype, *Flabellina karreri* Berthelin, 1880.

Conomiogypsinoides Tan, 1936. Ingen. Nederl.-Indië, Mijn. en Geol., 3de Jaarg. no. 3, pp. 51, 52. New subgenus of *Miogypsinoides*.

Dentalinella Wedekind, 1937. Einführ. in die Grundlagen der Hist. Geol., Bd. 2, Teil 2, p. 94. Genotype, *D. cuneata* Wedekind.

Echinofolliculina Dons, 1935. K. Norske Vidensk. Selsk. Trondhjem, vol. 7, p. 28, Genotype, *E. mortensi* Dons.

Euglypha Entz, 1877. Természetrajzi Füsetek, vol. 3, p. 162. Genotype, *E. pusilla* Entz.

Flourensina Marie, 1938. Bull. Soc. géol. France, ser. 5, vol. 8, p. 92, Genotype, *F. douvillei* Marie.

Haplophragmella Rauser-Cernoussova, Beljaew, and Reitlinger, 1936. Acad. Nauk U.S.S.R., Trudy Polar Commission, ser. 28, p. 215. Genotype, *Endothrya panderi* Moeller, 1879.

Helicocyclina Tan, 1936. Proc. Kon. Akad. Wetensch. Amsterdam, vol. 39, p. 994. Genotype, *Helicolepidina paucispira* Barker and Grimsdale, 1936.

Helicolepidinoides Tan, 1936. Proc. Kon. Akad. Wetensch. Amsterdam, vol. 39, p. 992. Genotype, *Helicostegina gyralis* Barker and Grimsdale, 1936.

Helicostegina Barker and Grimsdale, 1936. Jour. Paleont., vol. 10, p. 233. Genotype, *H. dimorpha* Barker and Grimsdale.

Ichthyolaria Fitzinger-Auer, 1938. Dissertation, Marburg, p. 20. New subgenus of *Frondicularia*.

Jadammina Bartenstein and Brand, 1938. Senckenbergiana, vol. 20, p. 381. Genotype, *J. polystoma* Bartenstein and Brand.

Kilianina Pfender, 1935. Grenoble Univ. Lab. Géologie, Travaux, vol. 19, p. 245. Genotype, *K. blancheti* Pfender.

Lacazopsis Douvillé, 1929. Bull. Soc. géol. France, ser. 4, vol. 29, p. 245. Genotytpe, *L. termieri* Douvillé.

Laevipeneroplis Sulc, 1936. Ann. de Protitstologie, vol. 5, p. 161. Genotype, *Peneroplis karreri* Wiesner, 1923.

Mirfa de Gregorio, 1890. Ann. Geol. Pal. Palerme, vol. 7-8, p. 260. Genotype, *M. subtetraedra* de Gregorio (Eocene, Alabama).

Nanicella Henbest, 1935. Jour. Washington Acad. Sci., vol. 25, p. 34. Genotype, *Endothyra gallowayi* Thomas, 1931.

Nautiloculina Mohler, 1938. Abh. Schweiz. Palaeont. Ges., vol. 60, p. 19. Genotype, *N. oolothica* Mohler.

Orbiculoidea Chapman, 1932. Proc. Roy. Soc. Victoria, vol. 45, p. 247. Genotype, *O. antipodum* Chapman. (Homonym of *Orbiculoidea* d'Orbigny, brachiopod.)

Ordovicina Eisenach, 1937. Palaeont. Zeit., vol. 19, p. 234. Genotype, *O. oligostoma* Eisenach.

Orthokarstenia Dietrich, 1935. Centralbl. Min., etc., Abt. B, p. 80. Genotype, *Orthocerina ewaldi* Karsten, 1856. (Cushman places this species in *Siphogenerinoides*, and *Orthokarstenia* is undoubtedly a synonym for this genus.)

Palaeokylix Eisenach, 1932. Palaeont. Zeit., vol. 14, p. 261. Genotype, *P. chitinosus* Eisenach.

Parrella Finlay, 1939. Trans. Roy. Soc. New Zealand, vol. 68, p. 523. Genotype, *Anomalina bengalensis* Schwager, 1866. (In this edition, this name appears in synonymy under *Pulvinulinella* Cushman.)

Paraspiroclypeus Hanzawa, 1937. Jour. Paleont., vol. 11, p. 116. Genotype, *Camerina chawneri* D. K. Palmer, 1934.

Pellatispirella Hanzawa, 1937. Jour. Paleont., vol. 11, p. 115. Genotype, *Camerina matleyi* Vaughan.

Plectophrys Entz, 1877. Természetrajzi Füzetek, vol. 3, p. 160. Genotype, *P. prolifera* Entz.

Protocyclina Paalzow, 1922. Abh. Nat. Geeol. Nürnberg, vol. 22. Genotype, *P. liasina* Paalzow (?not a foraminifer).

Pyramis Colani, 1924. Mém. Soc. géol. Indo-Chine, Hanoi, vol. 11, fasc. 1, p. 181. Genotype, *P. parva* Colani.

Ramulinella Paalzow, 1932. Jahresb. Ver. Nat. Würtemberg, vol. 88, p. 135. Genotype, *R. suevica* Paalzow.

Sagrinnodosaria Jedlitschka, 1931. Firgenwald, vol. 4, p. 125. Genotype, *Nodosaria abyssorum* H. B. Brady. Since *N. abyssorum* is already the genotype of *Siphonodosaria* A. Silvestri, 1924, this genus becomes a synonym of *Siphonodosaria*.

Vacuolispira Tan, 1936. Ingen. Nederl.-Indië, vol. 3, pt. 4, Mijn. en Geol., p. 177. Genotype, *Pellatispira inflata* Umbgrove.

Xenotheka Eisenach, 1937. Palaeont. Zeit., vol. 19, p. 239. Genotype, *X. klinostoma* Eisenach.

In addition, may be noted Tan's reclassification of *Cycloclypeus* in 1932 (Wetensch. Mededel. no. 19, Dienst Mijnb. Nederl.-Indië), in which a division of *Cycloclypeus* Carpenter into three subgenera is proposed: *Cycloclypeus* s.s., *Katacycloclypeus* Tan, and *Radiocycloclypeus* Tan, on the basis of nepeionic structure.

BIBLIOGRAPHY—The organization of the material in this section of the new edition is the same as that of the former edition and carries 454 new references. A welcome improvement is the use of running heads on right-hand pages to indicate the divisional units within which these pages lie, thus obviating the need of turning back to preceding center headings in the text. The very practical black-faced type for authors' names formerly used has been replaced by caps and small caps of the same font as the general text, but the excellent plan of indentation still facilitates ready reference. As previously, no consistency in the use of italics for generic and specific designations in titles has been adopted. Editorial rules do not require faithful duplication of the style used in the original paper, and it would be more convenient for use, if such names were printed according to the usual rules. It is somewhat difficult to understand why certain papers on generic groups lie under "Morphology, Technique, etc." and other papers of the same character lie under "Nomenclature" or "Classification and General." An important paper by Earl Myers has been overlooked in Section IX: The life-cycle of *Spirillina vivipara* Ehrenberg, with notes on morphogenesis, systematics, and distribution of the Foraminifera; Jour. Roy. Mic. Soc., vol. 56, pp. 120-146, pls. 1-3, 1936. The last paper of this section (by R. Wright Barker) is of considerable value

for its bibliography, but since its main purpose is to present a compilation of significant data rrelating to the micropaleontology of the Tampico embayment, it could readily be missed by those wishing to marshall the references on this classic geologic area. Just why R. Wright Barker is associated with the W's instead of with the B's is somewhat puzzling, and workers should keep this error in mind when looking for papers important in studying the American Tertiaries. Even though a bibliography in such a volume must necessarily be selective, a number of highly significant papers have been omitted.

KEY—This unit of the third edition, like that of the second, is one of the most valuable sections of the classification in stressing the significant features of each genus. All the newly accepted generic structures in this volume are included in the key, except *Haeuslerella* and *Earlmyersia*, which are, however, figured on the accompanying plates. *Silicotextulina* and *Biplanispira* are included in the key but are not illustrated, for reasons that become obvious to the reader. Subgenera are not mentioned, except in the keys to orbitoids and fusulinids. Page references throughout the key and on the descriptions of accompanying plates, as in the last edition, make reference work most efficient.

INDEX—The typography of names in the index remains the same and has proved a very convenient guide. A number of names that appear in the text are not to be found in the index, but so far as any check has been made the missing names comprise only some doubtful generic forms that are discussed under family headings, though most of these names are included in the index, and it is assumed that all should have been.

The names of families and subfamilies are still unaccompanied by the names of the originators, dates of introduction, and synonymies. Under generic headings synonymies show the same restraint as those in former editions, and additions are rare. A number of new treatments of many genera are on record and could well have been cited in the synonymies. L. M. Davies, for example, in 1930 and 1939, contributed some very significant observations on the genus *Dictyoconus;* in 1932 he presented very significant observations on the genotype of *Rotalia;* and his 1939 treatments of *Chapmanina, Cushmania, Gunteria, Orbitolina,* and *Marginipora* are strategic. Glaessner's new family Ceratobuliminidae (1937) is worthy of more stress than the bibliographic references accords it (p. 387). If the genera *Vaginulinopsis* and *Marginulinopsis*, treated so expertly and regarded as valid by Thalmann in 1937, are not here accepted as distinct structures, they would be welcome names in synonymies to express the relationships as the author sees them. Pointed reference to such new papers, either in synonymy or following the descriptions of the genera, would be helpful to the student.

For several years it has been known by many European paleontologists that the type specimen of *Orbitolina gigantea* d'Orbigny can not possibly be a foraminifer; after studying the specimen L. M. Davies published during the past year his findings, which are in agreement with the general opinion regarding its position, and pointed out a way to overcome the difficulty of having to relegate the name *Orbitolina* to the corals and of necessitating an entirely new name for such forms as have been called *Orbitolina* for so many decades. It is therefore surprising to discover that the genotype in this edition is still *O. gigantea* without further comment.

Students of the Foraminifera, both Recent and fossil, have every reason to be grateful to Dr. Cushman for these periodic compilations of scattered contributions to this science. That so intricately constructed a volume is so complete and so free of discrepancies and errors is remarkable. Readers who have never handled complicated manuscripts either as authors or as editors can hardly appreiate the tremendous amount of exacting labour involved in their preparation. Both beginning students and experienced workers are especially favoured in having so compact and so informative a guide.

BUREAU OF ECONOMIC GEOLOGY,
AUSTIN, TEXAS.

FLORA OF INDIANA. By Charles C. Deam. Department of Conservation, Indianapolis, 1940. Price $3.50.

The Department of Conservation of the State of Indiana has just issued the Flora of Indiana, the life long work of Charles C. Deam. The volume measures 7¼" × 10¼" (18 × 26 cm.), and contains 1,236 pages and a frontispiece of *Quercus Deamii* Trelease. Four full pages of maps at the close show the dates of killing frosts, autumn and spring, the floral areas of Indiana and a guide to the counties shown in outline in the distributional maps of the text. Page nine is a very pleasing foreword written by Dr. Stanley Coulter. As he says, it is difficult to write a suitable foreword to such a notable book, likewise it is equally difficult to write a review of such a monumental piece of work.

It is written in the conventional form of floras; the language is direct and simple. A glossary defining technical words occupies five pages at the close of the book. An equal number of pages is devoted to habitat and distribution terms. Thirty-one pages are given to the bibliography. All of the publications cited in it except four are in Deam's library. He is an indefatigable collector of books dealing with the flora of Indiana; no stone is left unturned in securing them; no expense is too great to acquire them and to have them suitably bound. One paragraph on page 19 is a well voiced protest against the state flower which Indiana has adopted.

The book treats of 587 native genera, 103 introduced genera, 1,838 native species, 302 introduced species, 279 native and 13 introduced varieties, 95 native and three introduced forms and 38 hybrids. Everyone who knows Deam realizes that he can go to the habitat of each one. The possible uses of each plant are mentioned, and Deam never fails to show his pharmaceutical knowledge.

The book itself is based primarily on the author's private collection numbering over 59,000 specimens. In addition to his own he has examined specimens in herbaria of the larger museums and most of the private herbaria in Indiana. In all he has examined 84,584 specimens. Making hhis own collection since 1914, he has traveled over 125,000 miles, and has collected plants in each of the 1016 townships in the state. The reader can rest assured that Deam knows where each of these townships is located and what plants of interest are found in it. There are 2,243 distributional maps indicating the habitat by counties of the specimens in the state and their location in public and private collections. No species is admitted unless it is based on an actual specimen in Deam's herbarium or in other herbaria. Only once or twice is a species recorded which is not found in the Deam collection.

The distributional maps also indicate the times of flowering of the different plants, based on the specimens in the Deam herbarium. Under each species is given a pleasing account of its distribution in the state and the type of locality in which it is found.

The reviewer can not speak from personal knowledge as to the nomenclature used in the book, but, knowing Deam as he does, he feels sure that the reader may be certain that the nomenclature is meticulously accurate. Difficult groups have been referred to specialists for classification. One of the most pleasing features of the Flora is the generous credit given to other workers. See table page 1115, and numerous places in the text. No one who ever collected an Indiana plant seems to have been omitted.

It is a work which reflects extreme credit upon the author and the Department of Conservation with which he was associated and which publishes the book at a nominal price.

The book itself is a model of bookmaking, printed on excellent paper and bound in such a manner that it may be laid on a table, opened in any place, and the pages remain as opened—just another little evidence of Deam's care in publishing the book. The Flora will remain a standard for many, many years and will ever remain a credit to its painstaking and tireless author. The chances are that Deam is now out in the field somewhere collecting more specimens for a possible supplement. He can not remain quiet and rest on his laurels.—M. W. LYON, JR.

THE PRINCIPLES OF INSECT PHYSIOLOGY. By V. B. Wigglesworth. E. P. Dutton and Company, New York, 1939. viii + 434 pp., 316 figs. $8.00.

Information on the physiology of insects has heretofore been either widely scattered in many scientific journals or more or less neglected in the general sections of textbooks of entomology. To have summarized this vast body of details and general principles from some 2000 different sources into a masterful and panoramic presentation of insect physiology, is the distinct achievement of the author of this timely and scholarly work.

In fifteen chapters all important stages of development, the basic functions of the insect body and its multitudinous physiological characteristics are treated in the light of the most recent contributions and demonstrated with suitable examples. Numerous carefully selected diagrams and illustrations, rarely seen in textbooks, supplement the text. Morphological and anatomical descriptions are limited to those indispensable for the understanding of the physiological discussions following them. The author's own contributions to this field of entomological research assure the reader of his far-reaching acquaintance with it. As a consequence, the book readily substantiates its author's claim that "insects provide an ideal medium in which to study all problems of physiology."

As a record of the rapid progress made especially in recent years, "The Principles of Insect Physiology" represents a milestone in the advancement of our knowledge of insects.—TH. JUST.

A LABORATORY GUIDE IN ENTOMOLOGY FOR INTRODUCTORY COURSES. By Robert Matheson. Comstock Publishing Co., Ithaca, N. Y. 1939. vii + 135 pp., 48 pls. $2.00.

Cornell entomologists have in the past done more than their share for the teaching of entomology through the preparation and publication of fundamental works. Recently, Professor Matheson has added to these his "Laboratory Guide" which corresponds largely to the work done in the beginning course in entomology at Cornell University. The "Guide" is made up of 28 "Studies" mainly concerned with the morphology and taxonomy of the larger and more important orders (nos. 1-21), but with adequate space given also to biological problems (nos. 22-28). An Appendix offers instructions for collecting, preparing, mounting, preserving and rearing insects. A Glossary and three useful references conclude the book. The plates either illustrate important representatives and types or may be labelled by the student. All pages can be removed, if so desired, and placed in private notebooks. If all "Studies" are carefully carried out, the student is bound to acquire a very thorough understanding of the fundamentals of entomology in preparation for further work in this field. In addition, the author has done a great service to those teaching entomology elsewhere by the publication of this excellent "Guide."—TH. JUST.